Dudley Knox Library, NPS
Monterey, CA 93943

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A SIMULATION MODEL OF
TACTICAL NUCLEAR TARGET ANALYSIS
AND DAMAGE ASSESSMENT

Joseph Carl Fernandez

June 1983

Thesis Advisor: J. K. Hartman

Approved for public release; distribution unlimited

T210096

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Dudley Knox Library, NPS
Monterey, CA 93943

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Simulation Model of Tactical Nuclear Target Analysis and Damage Assessment		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis June 1983
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Joseph C Fernandez		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey California 93940		12. REPORT DATE June 1983
		13. NUMBER OF PAGES 123
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Combat Modelling	Personnel	Infantry
Nuclear	Vehicles	
Stochastic	SIMSCRIPT	
Damage	Armor	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This thesis presents a Nuclear Targeting and Effects program that is intended for inclusion in the Simulation of Tactical Alternative Responses (STAR) combat model. It is presented as a stand alone program, written in SIMSCRIPT, which can be easily modified as a subroutine for any high resolution combat model requiring tactical nuclear effects simulation. When presented with a group of targets which are deemed suitable for attack by tactical nuclear weapons, the program will select units to fire, select proper yields for multiple yield weapon systems and assess casualties

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

among Armor and Infantry within the target area.

Approved for public release; distribution unlimited.

A Simulation Model of Tactical Nuclear Target Analysis and Damage Assessment

by

Joseph Carl Fernandez
Captain, United States Army
B.S., San Diego State University, 1970

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
June, 1983

c. 1

ABSTRACT

This thesis presents a Nuclear Targeting and Effects program that is intended for inclusion in the Simulation of Tactical Alternative Responses (STAR) combat model. It is presented as a stand alone program, written in SIMSCRIPT, which can be easily modified as a subroutine for any high resolution combat model requiring tactical nuclear effects simulation. When presented with a group of targets which are deemed suitable for attack by tactical nuclear weapons, the program will select units to fire, select proper yields for multiple yield weapon systems and assess casualties among Armor and Infantry within the target area.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

This thesis presents a nuclear targeting and effects program that is intended for inclusion in the Simulation of Tactical Alternative Responses (STAR) combat model. It is presented as a stand alone program, written in SIMSCRIPT, which can be easily modified as a subroutine for any high resolution combat model requiring tactical nuclear effects simulation.

When presented with a group of targets which are deemed suitable for attack by tactical nuclear weapons, the program will select units to fire, select proper yields for multiple yield weapon systems and assess casualties among Armor and Infantry within the target area.

A. CAPABILITIES

The model in this thesis analyzes the given targets for destruction by nuclear weapons. In so doing it;

1. Can handle any number of targets.
2. Can handle any number of nuclear capable firing batteries each of which may have any number of different yield rounds available.
3. Can keep track of any number of friendly maneuver units.
4. Provides for friendly troop safety.
5. Represents targets as composed only of personnel and tanks.
6. Assesses damage to each individual target element in a stochastic manner rather than as an expected value.
7. Assesses damage caused by blast, heat and radiation.

B. LIMITATIONS

Some of the items listed as limitations are such only because not all weapons are included in the data base or not all possible target elements are included in the targets. Most of the following can be input into the model with a moderate amount of work. The model does not;

1. Use free flight rockets, missiles or Air Force delivered munitions.
2. Use strategic weapons.
3. Consider collateral damage avoidance.
4. Model any other effects such as NBC warning and reporting, optimum time of exit for units caught in fallout areas, crossing fallout areas, decontamination or medical evacuation and treatment of casualties.

C. THISIS PREVIEW

Chapter II will briefly review the effects of nuclear weapons. The damage mechanisms will be introduced while formulas and methodology for building the assessment phase of the model will be developed.

Chapter III will discuss some of the more relevent definitions the reader must become familiar with and then will show how the analyst in the field solves the target analysis problem. The model will mimic this manual solution in order to arrive at the same solution a field anaylst would get.

Chapter IV will discuss the mechanics of how the model works without being code specific. Some simplifying assumptions will be made and approximations will be offered to reduce the processing time.

Chapter V will explain the code of the model. Each routine and function will be discussed separately. All global variables, permanent and temporary entities along with their attributes, set membership and ownership are explained and must be fully understood to comprehend the model.

Chapter VI will identify possible areas for further research. Areas include a method for optimum assignment of batteries/yields to targets, standard field operations taken during and after a nuclear burst and inclusion of other elements into the target area.

II. EFFECTS OF NUCLEAR WEAPONS

A. INTRODUCTION

A nuclear explosion, like any conventional explosion, results from the very rapid release of a large amount of energy in a small space - an energy density. In simple mechanics, the liberation of energy is manifested as pressure, heat and, in the case of nuclear weapons, ionizing radiation. The damage mechanisms of nuclear weapons are refered to as blast, thermal radiation and nuclear radiation. Damage caused by blast is further divided into damage caused by overpressure and by dynamic pressure.

The heat of the weapon is almost instantly transmitted through thermal radiation to every object within line-of-sight constraints. Objects at distances of several miles will begin to absorb enough heat to cause combustable materials to burst into flame. The pressure of the weapon is transmitted through a blast wave which emanates spherically from the point of detonation and travels at speeds closely related to the speed of sound. Upon encountering a target element the blast wave may crush the target because of a high overpressure, or it may destroy it by translation - the act of tumbling it about on the ground.

Finally, the nuclear weapon has associated with it the harmful, highly penetrating nuclear radiation. The explosion emits alpha and beta particles, neutrons and gamma rays. Due to their charge, alpha and beta particles have no military significance in weapon detonation and are hereafter ignored.

Neutrons are one of the basic building blocks of the atomic nucleus and have no electronic charge. It is the lack of charge which allows deep propagation and penetration.

Gamma rays are electromagnetic radiation. They are identical in composition to light, radio waves, and X-rays except for wave length and are not easily stopped or absorbed.

Both neutron and gamma radiation are refered to as ionizing radiation. The biological implication of this is that as the radiation passes through living tissue it ionizes some of it, changing the chemical structure into a different, non-functional substance. Essentially, it kills cells or inhibits them from functioning as intended.

B. ENERGY DISTRIBUTION

The percentages of total energy appearing as blast, thermal radiation, and nuclear radiation depend mostly on the altitude at which the blast occurs. For bursts within the lower atmosphere the percentages are about 50, 35, and 15 percent respectively. Thus, as with conventional weapons, blast is the dominant factor.

C. BLAST

Targets are damaged by a crushing mechanism caused by overpressure or by a tumbling action caused by dynamic pressure.

1. <u>Overpressure</u>

Overpressure is the crushing force applied to a target. When an object begins to interact with the blast wave, the leading edge of the object is subjected to an increase in pressure while the trailing edge is still at

ambient pressure. This produces a quick net force away from the blast. As the blast wave envelopes the object the entire exterior is subjected to an increased pressure while the interior remains at ambient pressure. Thus, a crushing force is applied to the exterior in an attempt to damage it. Lungs and eardrums are easily damaged by this mechanism at overpressures of 6 psi.

2. Dynamic Pressure

As the name implies, this is the pressure which is associated with high winds. Dynamic pressure can damage targets by pushing, tumbling and tearing them apart. Targets damaged primarily by dynamic pressure are called drag sensitive. With the exception of heavily armored vehicles such as tanks, most military materiel is drag sensitive. Personnel in the open are drag sensitive and are damaged easily by flying debris.

3. Blast Wave Characteristics

Upon detonation, a blast wave of compressed air moves spherically away from the point of detonation. The wave speed is well in excess of the speed of sound. As the wave propagates, the speed diminishes until it exhausts itself. The quantification of three blast wave characteristics is essential to simulating blast casualties. The characteristics are overpressure and dynamic pressure as well as the time of arrival of the blast wave.

a. Overpressure

Fig. 2.1 [Ref. 1: p. 113] is a graph relating distance from ground zero to height of burst with overpressure as a parameter. The figure is for a 1 KT weapon but can be used for any weapon with the proper scaling laws applied. Equation 2.1 is the cube root scaling equation which will apply here and in the next two sections.

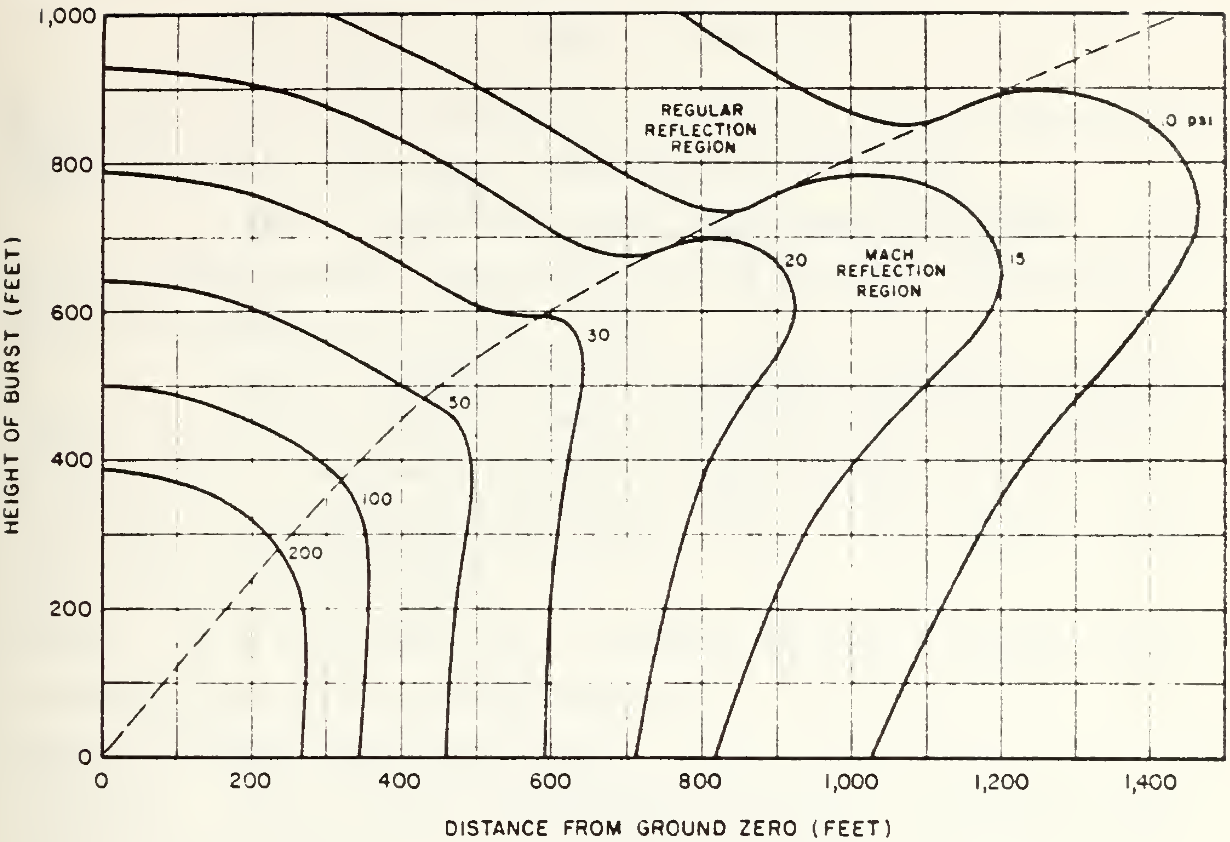

Figure 2.1 Scaled Values of 1 KT Overpressure.

$$\frac{d}{d_1} = \frac{h}{h_1} = \frac{t}{t_1} = W^{1/3} \qquad (2.1)$$

An example will demonstrate how the method works.

Given: an 8 KT weapon is detonated at a height of 200 ft.

Find: The peak overpressure at 1200 ft. from ground zero.

Solution: The corresponding height of burst for a 1KT burst is;

$$h_1 = \frac{h}{W^{1/3}} = \frac{200}{8^{1/3}} = 100 \text{ ft.}$$

and the ground distance is

$$d_1 = \frac{d}{W^{1/3}} = \frac{1200}{8^{1/3}} = 600 \text{ ft.}$$

From Fig. 2.1, at a distance of 600 ft. with a height of burst of 100 ft. the peak overpressure is 30 psi.

Ref. 1 has two other overpressure graphs. One is for overpressures of 10,000 to 100 psi and the other is for overpressures of 15 to 1 psi.

These problems may be worked in reverse to solve for the optimum height of burst if one knows the required overpressure to defeat a target. This concept will be quite important in chapters III and IV. An example will demonstrate the method.

Given: An 8 KT weapon will be used against a target which is defeated by 10 psi overpressure.

Find: Optimum height of burst.

Solution: The optimum solution is the one which produces the required effect at the farthest distance from the burst. From Fig. 2.1 the distance is 1460 ft. and the height of burst is 740 ft. From equation 2.1 the actual height of burst and actual distance where the effect will be felt can be found.

$$d = d_1 \cdot W^{1/3} = 1460 \cdot 8^{1/3} = 2920 \text{ ft.} = 890 \text{ meters}$$

$$h = h_1 \cdot W^{1/3} = 740 \cdot 8^{1/3} = 1480 \text{ ft.} = 451 \text{ meters}$$

In this manner, the optimum height of burst for this damage mechanism may be found for any target when the required overpressure and expected yield are known. This will be essential later in defining what is known as the governing effect.

b. Dynamic Pressure

Fig. 2.2 [Ref. 1: p. 117] is a graph relating distance from ground zero to height of burst with dynamic pressure as a parameter. Like Fig. 2.1, it is for a 1 KT

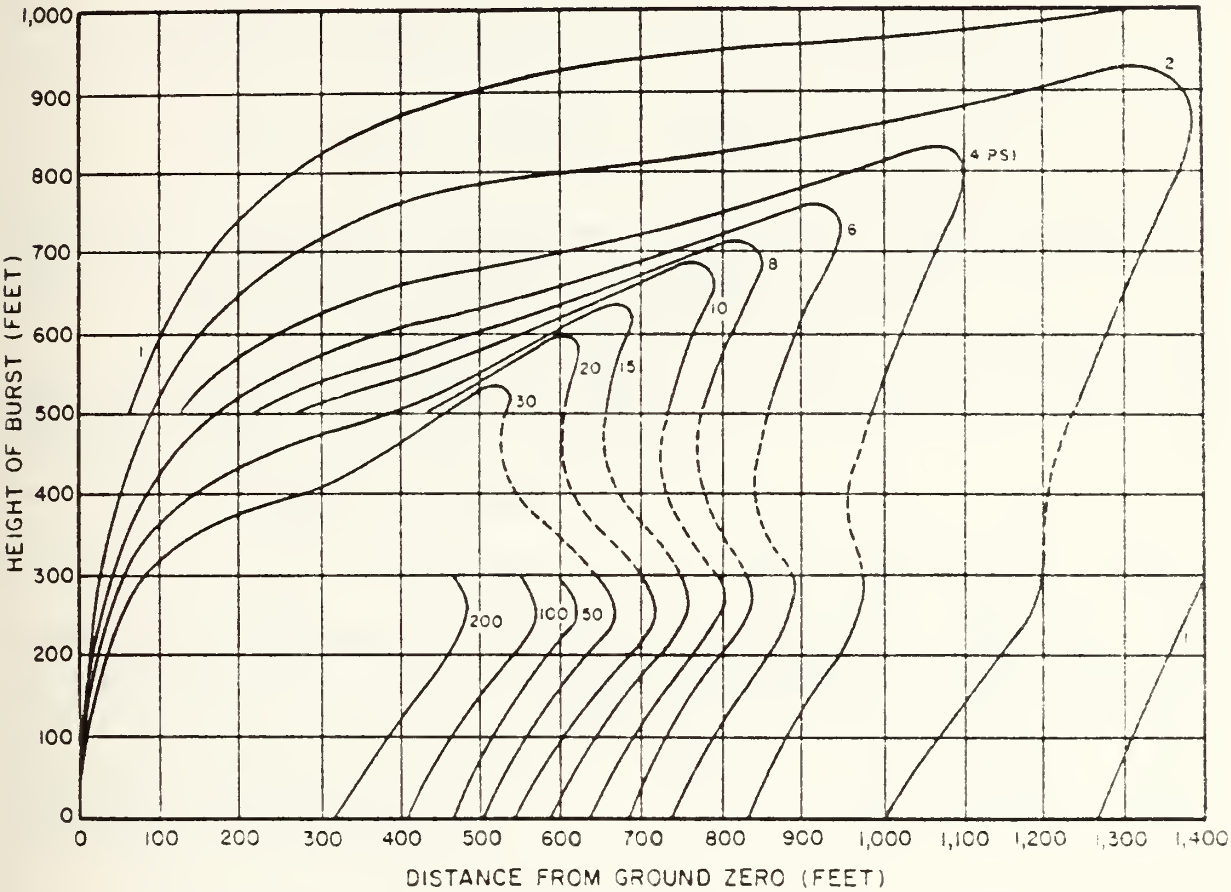

Figure 2.2 Scaled Values of Dynamic Pressure.

detonation, but the same cube root scaling equation applies. Another example will demonstrate the method.

Given: a 27 KT weapon is detonated at a height of 600 ft.
Find: The dynamic pressure at 2400 ft. from ground zero.

Solution: The corresponding height of burst for a 1KT burst is;

$$h_1 = \frac{h}{W^{1/3}} = \frac{600}{27^{1/3}} = 200 \text{ ft.}$$

and the ground distance is

$$d_1 = \frac{d}{W^{1/3}} = \frac{2400}{27^{1/3}} = 800 \text{ ft.}$$

From Fig. 2.2, at a distance of 800 ft. with a height of burst of 200 ft. the dynamic pressure is 8 psi.

In a manner analogous to that offered in the section above, an optimum height of burst may be found for targets damaged by dynamic pressure.

c. Time of Arrival

Fig. 2.3 [Ref. 1: p. 121] is a graph relating distance from ground zero to height of burst with the time of arrival of the blast wave as a parameter. Like Figs. 2.1 and 2.2, it is for a 1 KT detonation, but the same cube root scaling equation applies. Again, an example will demonstrate the method.

Given: a 64 KT weapon is detonated at a height of 2000 ft.
Find: The time of arrival of the blast wave at a distance of 3 miles from ground zero.
Solution: From previous techniques;

$$h = 500 \text{ ft.} \quad d = 3960 \text{ ft.}$$

From Fig. 2.3 the time for a 1 KT burst is 2.8 sec. and

$$t = t_1 \cdot W^{1/3} = 2.8 \cdot 64^{1/3} = 11.2 \text{ sec.}$$

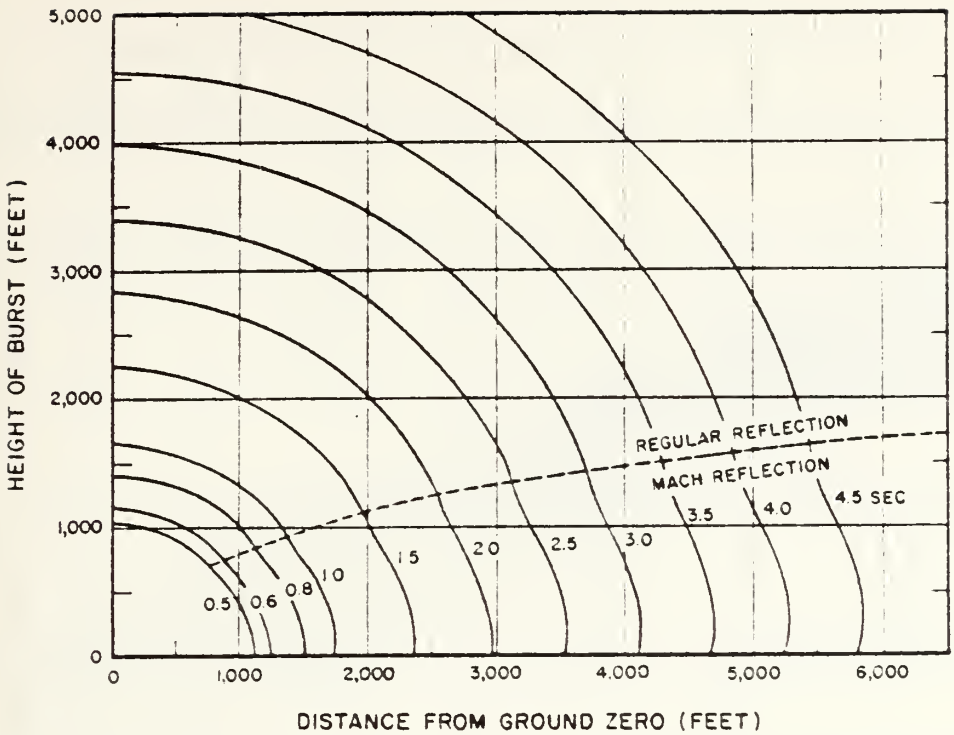

Figure 2.3 Scaled Values of 1 KT Blast Wave Arrival Time.

It is interesting to note that as the yield increases, the time of arrival increases which means the speed of the blast wave is decreasing.

D. THERMAL RADIATION

Thermal radiation is a radiant heat transfer mechanism which propagates with the speed of light. Upon burst every object with line-of-sight to the burst begins to absorb heat at a rate predicted by the thermodynamic laws governing thermal radiation. Combustable materials will ignite if the rate and exposure time are sufficiently high. Personnel will suffer first, second, and even third degree burns if reaction times are slow and absorption rate is high. Fig. 2.4 [Ref. 1: p. 291] shows the relationship between yield, distance from ground zero and the expected heat absorption.

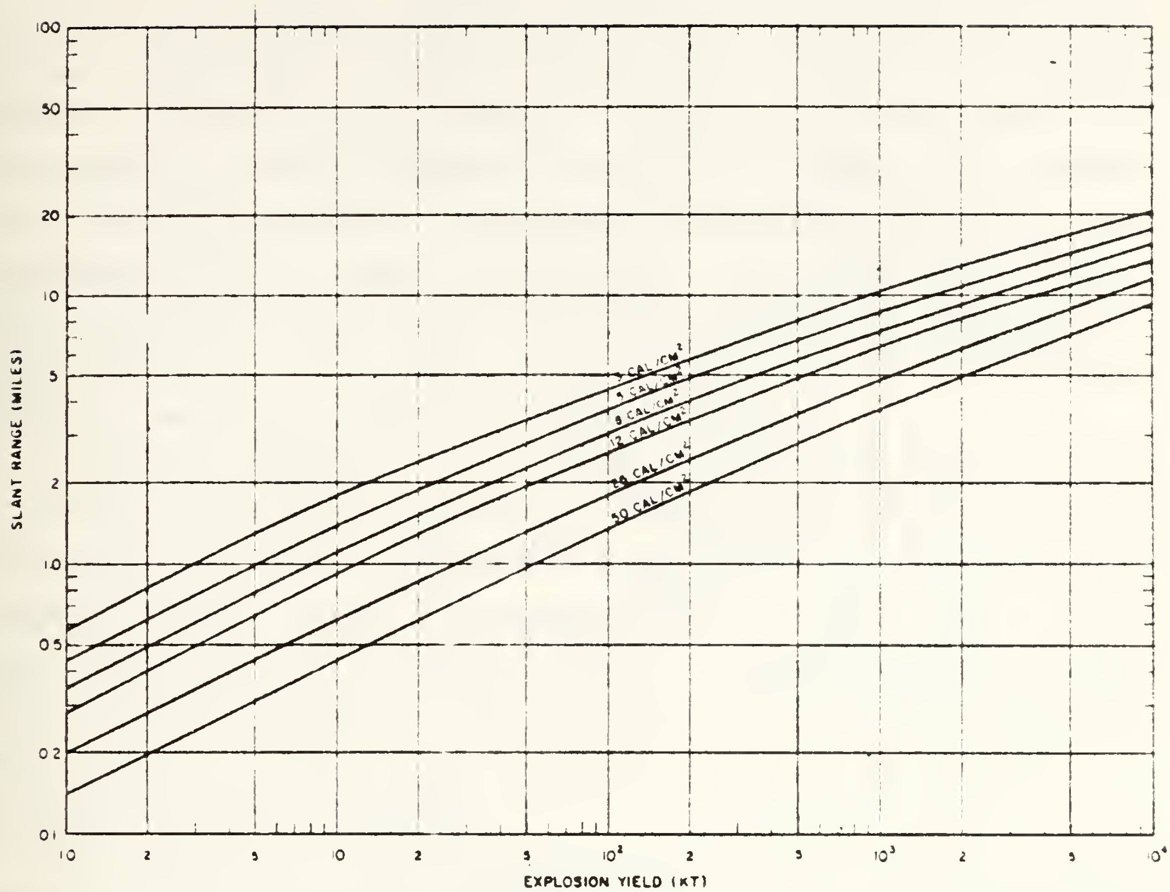

Figure 2.4 Heat Abscrption as a Function of Range and Yield.

$$Q = 1561 \cdot \frac{Yield^{.5051}}{Cal^{.4885}} \qquad (2.2)$$

Equation 2.2 is the linear regression for Fig. 2.4.

Nuclear bursts emit two distinct pulses of thermal radiation. The second one contains about 99 percent of the destructive power. It consists of visible and infrared light which is poorly attenuated by normal atmospheric conditions.

Any condition which affects the visibility or transparancy of the air will modify the transmission of thermal radiation. Clouds, smoke, fog, rain and snow will absorb and scatter the energy. Also, a cloud cover above the burst can reflect energy back to the target and increase the thermal radiation that would have otherwise traveled harmessly into the sky. Obviously, any solid object which will not become a victim of thermal radiation will provide adequate protection. Such objects include, hills, foxholes, bunkers, vehicles, trees and other people.

As stated earlier, the exposure time would be a factor in determining total exposure. However, in actual tests it was discovered that combustable materials such as wood frame houses charred almost instantaneously. Also, due to the short duration of the thermal pulse, a steady state thermal heat transfer condition was not achieved and the buildings were able to absorb and dissapate the initial burst of energy and avoid ignition.

The point of the preceeding paragraph is that reaction time of a potential absorber, such as a soldier on the battlefield, will play an insignificant part in determining thermal radiation effects.

Fig. 2.5 [Ref. 1: p. 314] shows the futility of avoiding burns if one is sufficiently close to ground zero. The following quote [Ref. 1: p. 313] sums it up;

> At the lower energy yields the thermal radiation is emitted in such a short time that no evasive action is possible. At the higher yields, however, exposure to much of the thermal radiation could be avoided if evasive action were taken within a fraction of a second of the explosion time. It must be remembered, of course, that even during this short period a very considerable amount of thermal energy will have been emitted from an explosion of high yield.

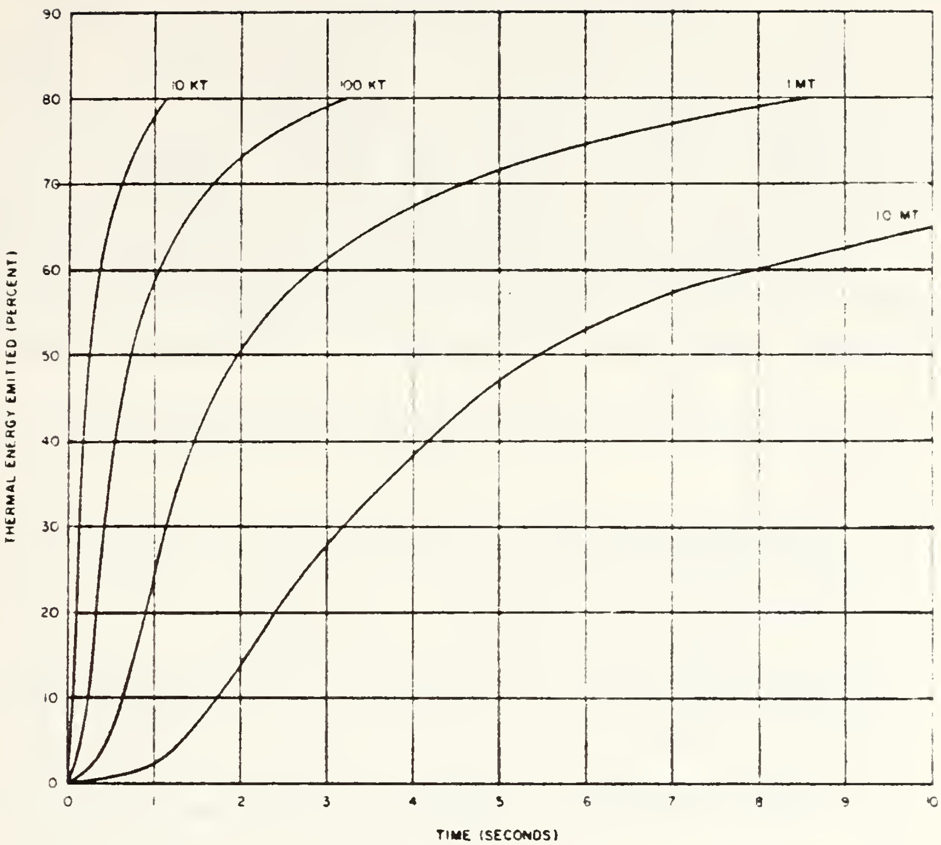

Figure 2.5 Energy Emmission as a Function of Time.

E. NUCLEAR RADIATION

1. Neutron Radiation

Upon detonation of a nuclear weapon a large quantity of free neutrons is released. The neutron release process is completed in less than a millionth of a second [Ref. 1: p. 340]. This is where the term prompt radiation comes from. However, due to collisions in the early stages of the detonation, actual escape may be delayed for a thousandth of a second - an insignificant comfort to potential targets.

Since the neutron has no charge it does not have a direct ionizing effect. The biologically harmful ionization occurs when the neutron collides with hydrogen in body

tissue. The neutron transfers its energy to the nucleus and frees it from the accompanying electron. Thus a free protron and a beta particle are allowed to cause ionizing tissue damage. Previously, beta had been disregarded as a source of concern. This was due to the impossibility of getting the particle into the body. In the context of the current discussion, it is already inside the body.

Fig. 2.6 [Ref. 1: p. 346] is a graph relating yield to the slant range to the burst with radiation absorption in

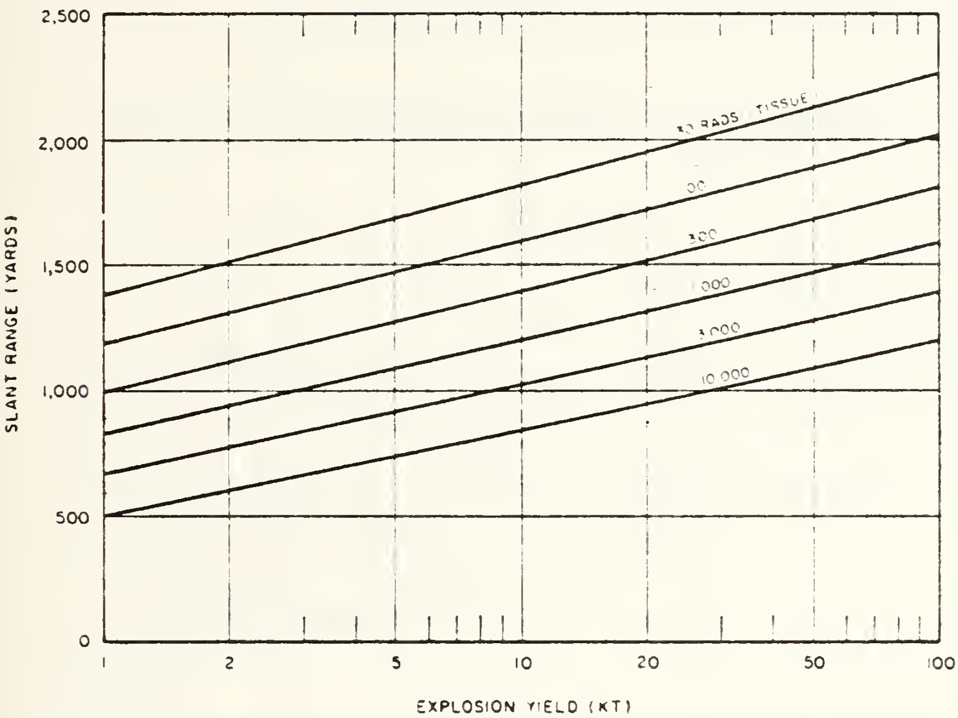

Figure 2.6 Neutron Radiation.

body tissue as a parameter. For a given yield and slant range, the absorbed radiation can be predicted. Equation 2.3 is the regression equation for Fig. 2.6.

$$N = \left(\frac{2368.47}{R - 150 \cdot \ln(\text{Yield})} \right)^{5.896} \qquad (2.3)$$

2. Gamma Radiation

Upon detonation of a nuclear weapon, gamma radiation is emitted. There are several mechanisms which cause gamma radiation at various times during and after the detonation. Ref. 1 (Sect 8.08 - 8.19) contains a detailed explanation of the mechanisms. Rather than delve into the sources of gamma radiation it is more important to predict absorption rates and figure out how to avoid absorption.

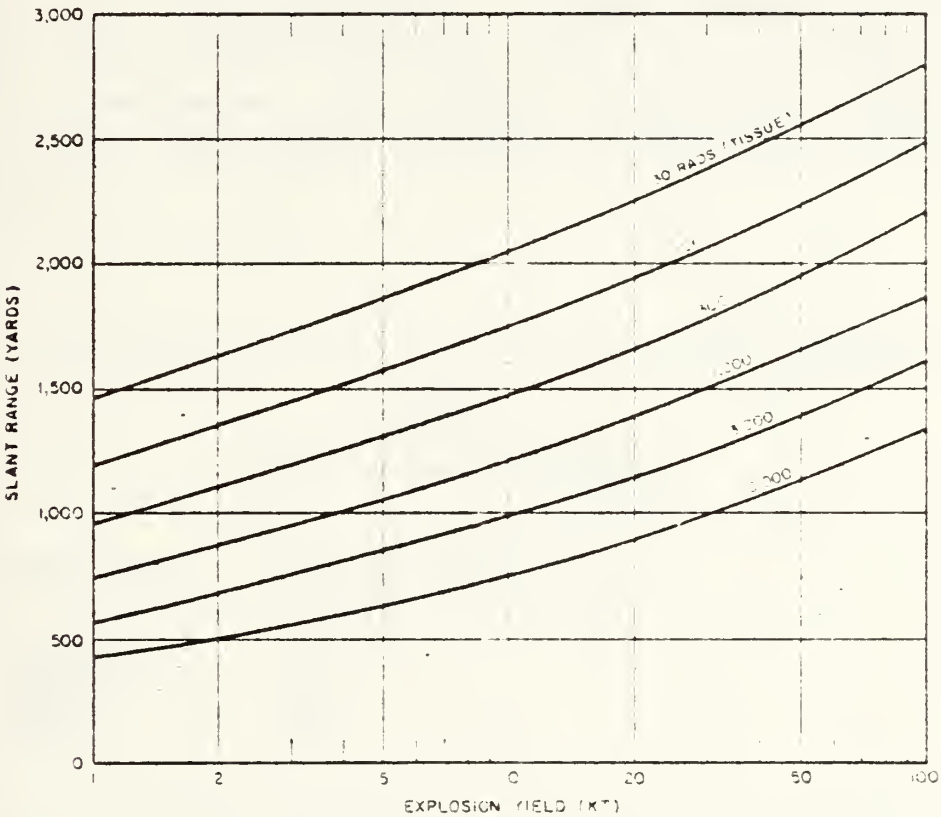

Figure 2.7 Gamma Radiation.

Fig. 2.7 [Ref. 1: p. 333] is similar to Fig. 2.6. For a given yield and slant range, the absorbed dose due to gamma radiation can be predicted. Equation 2.4 is the regression equation for Fig. 2.7.

$$G = 46166 \frac{e^{.5599 \cdot \sqrt{Yield}} \cdot e^{.0001 \cdot Yield \cdot R}}{e^{.0058 \cdot R}} \qquad (2.4)$$

Since gamma radiation is just light in a certain range of the electromagnetic spectrum, it behaves in accordance with the same laws, such as absorption. However, common opaque objects such as steel, concrete, paper, etc. which reflect or totally absorb visible light, only absorb a portion of the gamma radiation. A common example of this is traveling into a tunnel with the radio on in the car. The reception weakens as the amount of shielding increases. Table I lists some common materials which could be used as protection.

TABLE I

Common Gamma Absorbers

Material	Tenth Value Thickness (inches)
Steel	3.3
Concrete	11
Earth	16
Water	24
Wood	40

The Tenth Value Thickness is that thickness of the specified material which will cut the radiation by a factor of 10. Thus, 3.3 inches of steel or 16 inches of earth will reduce a 500 rad. dose to 50 rads. The addition of another 3.3 inches of steel will further cut the dose to 5 rads.

Thus,

$$D = \frac{D_0}{10^{T/T_1}} = D_0 \cdot 10^{-T/T_1}$$

where;

D is the predicted absorbed dose

D_0 is the unprotected dose

T is the thickness of protective material.

T_1 is the tenth value thickness.

III. NUCLEAR TARGET ANALYSIS

A. DEFINITIONS

Before beginning to make a weapon selection it is necessary to understand the terms peculiar to the subject. Some of the more important ones are presented here while the more obvious ones are found in the glossary.

1. Radius of Target (RT)

This is the actual radius of the target or an equivalent radius if the target is equatable to a circle. Ref 2 contains a nomograph to determine the appropriate RT for targets equatable to a circle. More importantly, the target elements within the target are assumed to be uniformly distributed.

2. Radius of Damage (RD)

This is the distance from ground zero at which a single target element has a 50% chance of receiving the specified degree of damage. The RD is a function of weapon yield, height of burst, casualty criterion and, in the case of personnel, the protection level. Fig. 3.1 shows a circle drawn with a radius from ground zero such that as many damaged elements (dark dots) are outside the circle as there are undamaged (light dots) inside the circle. Thus, an element at RD is said to have a 50% chance of becoming damaged.

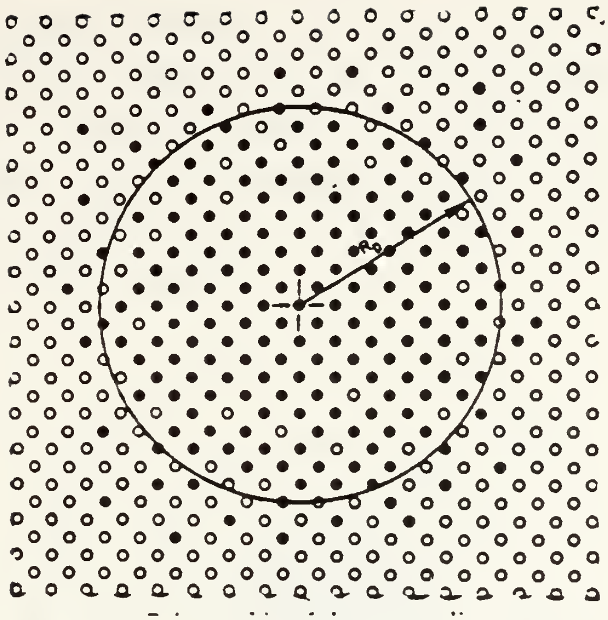

Figure 3.1 Radius of Damage.

3. Minimum Radius of Damage (MIN RD)

If the firing of a large number of rounds against a target was simulated, a probability distribution for the RD would begin to emerge. Fig. 3.2 is a cumulative distribution function for a hypothetical RD distribution. The MIN RD is as marked and is equalled or exceeded 90% of the time.

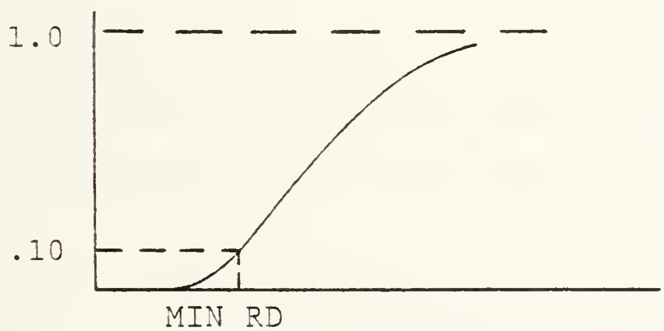

Figure 3.2 CDF of RD.

4. Circular Error Probable (CEP)

If a large number of rounds obeying a circular normal distribution were fired at ground zero and the impact points plotted, then CEP would be defined as that distance from ground zero that is exceeded as often as not. Fig. 3.3 shows an idealized plot of such firings. A circle of 1 CEP includes 50% of the rounds.

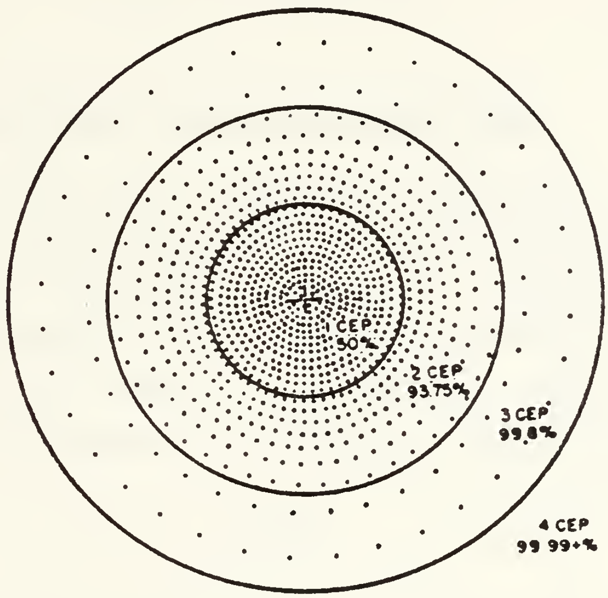

Figure 3.3 Circular Normal Distribution of Impact.

The distribution of impacts is assumed to have a bi-variate normal distribution about the aim point with equal variances and a zero correlation coefficient. Thus, a relationship between CEP and variance can be determined and is;

$$CEP = 1.1774 \cdot \sigma \tag{3.1}$$

5. Circular Distribution 90(CD90)

CD90 is very much like CEP except that 90% of the rounds are expected to fall within 1 CD90 of ground zero. When a priority target is being considered it is CD90 which is used as the dispersion parameter. The relationship between CD90 and CEP is

$$CD90 = 1.83 \cdot CEP \tag{3.2}$$

6. Probable Error Height-of-burst(PEH)

Similar to CEP, but in one dimension, the PEH is that distance above and below the desired height of burst in which 50% of the rounds are expected to function. Vertical delivery is assumed to be normally distributed about the desired height of burst. Therefore, the relationship between PEH and standard deviation is easily calculated as;

$$\sigma = \frac{PEH}{.67} \tag{3.3}$$

Most fuzing mechanisms are highly reliable and accurate. This ensures optimum height of burst and maximum casualties. It also allows some simplifying assumptions in Chapter IV.

7. Governing Effect

Most targets are affected by more than one damage mechanism. In order to simplify the analysis the range at which a target is damaged is tabulated and the effect corresponding to the largest range is selected as the governing effect. Table II lists hypothetical ranges for effects for exposed personnel and personnel in open foxholes.

TABLE II

Governing effect

Effect	Range (meters) Exposed	Fox hole
Overpressure	575	575
Dynamic pressure	225	N/A
Thermal radiation	950	N/A
Nuclear radiation	600	250

For exposed personnel, it would appear that thermal radiation is the governing effect. However, due to the unpredictibility of target posture, thermal radiation is never used as the governing effect [Ref. 3: P. 23]. Also, it is almost universally true that the effects of overpressure are felt at a greater range than the effects of dynamic pressure. This leaves only two criteria to compete for governing effect - blast due to overpressure and nuclear radiation. In table II, the governing effect for exposed personnel is nuclear radiation and for personnel in foxholes it is overpressure.

8. <u>Desired Height of Burst(DHOB)</u>

The DHOB is the maximum of two possible HOB.

It is usually desirable to obtain a low air burst without causing fallout. Eq. 3.4 is the formula for calculating the height of burst fallout safe (HOBfs) for yields less than 100 KT and Eq. 3.5 is the formula for calculating the HOBfs for yields greater than 100 KT.

$$HOBfs = 30 \cdot W^{1/3} \tag{3.4}$$

$$HOBfs = 55 \cdot W^{1/3} \tag{3.5}$$

W is the expected yield plus 10%.

Obviously this will produce fallout in 50% of the rounds. Therefore, a safety buffer of 3.5 PEH is added to HOBfs. This quantity is now refered to as HOB99 - the HOB at which there is a 99% chance of no fallout.

Depending upon the type of target and command guidance, there is a HOB which will cause optimum damage (HOBopt). This was seen earlier in the discussion on overpressure and dynamic pressure and the governing effect section above. The desired HOB (DHOB) is the maximum of HOB99 and HOBopt. In most cases, HOBopt is greater than HOB99 and is, therefore, the listed HOB. It is only when PEH becomes large that HOB99 is greater than HOBopt and the DHOB must be raised above HOBopt, thus reducing expected coverage.

9. Ground Zero (GZ)

The point on the ground directly below the position where the round actually detonates.

10. Desired Ground Zero (DGZ)

The actual aim point. The DGZ might not be the center of the target as will be seen later. GZ is only a single realization of the DGZ and is not known until after the detonation.

B. DAMAGE ESTIMATION

1. Coverage

To cause maximum damage, the round must be targeted at the center of the target. For various reasons, it may be necessary to deliberately shoot at a location other than the target center. If RT and RD are of the same order of magnitude, then a loss in coverage will result as shown in Fig. 3.4.

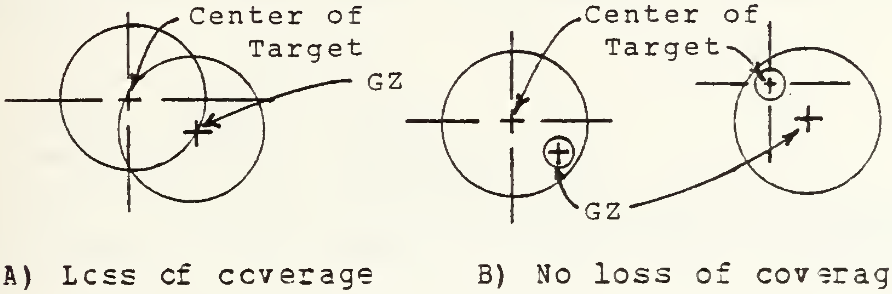

Figure 3.4 Loss of Coverage Due to Offset.

The analyst uses coverage tables from reference 2 in making the analysis. Fig. 3.5 is a sample of one such table. Each weapon system and yield has a complete set of tables. A set includes;

1. Immediate permanent, immediate transient and latent lethalities to exposed personnel, personnel in open fox holes and personnel in tanks (9 tables)
2. Moderate damage to tanks, wheeled vehicles and towed artillery (3 tables)

For each range and RT combination, there are two coverage figures listed. The first is a high assurance figure to be used when planning an attack on a priority target. There is a 90% chance of obtaining the listed coverage of the specified damage when using this figure.

The second figure is an expected coverage. There is a 50% chance of obtaining the listed coverage of the specified damage when using this figure.

2. Choosing the Correct Round

It quickly becomes obvious that there will be more than one weapon system which is adequate. The question is, "Which one is best?" The answer depends upon current guidance from the chain-of-command. Several policies are possible;

A. Select maximum yield.
B. Select maximum coverage.
C. Select minimum yield of the adequate possibilities.
D. Select minimum coverage of the adequate possibilities.

This model uses maximum coverage. In order to provide for friendly toop safety, it will be seen that maximum yield may not provide maximum coverage.

C. METHODS OF ANALYSIS

Current doctrine allows several methods of nuclear target analysis ranging from visual to preclusion oriented. Only two methods use detailed mathematical analysis. They are called the index method and the numerical method.

The index method requires that the desired ground zero be the center of the target. The numerical method allows the desired ground zero to be deliberately offset from the target center.

1. Index Method

The index method is the easiest and quickest method. To use this method the analyst needs only the appropriate table(s), the range from the applicable weapon delivery

system and the target radius. The appropriate table is determined by target type, desired effects, weapon type and weapon yield. Fig. 3.5 is a typical table for personnel in the open, latent lethatities, short range cannon, 1 KT yield.

COVERAGE TABLE (Distances in meters) — **SHORT RANGE CANNON 1 KT**

EXPOSED PERSONNEL - LATENT LETHALITY
LOW AIRBURST

	EFFECTIVENESS								PROB		ACCURACY DATA			
	RADIUS OF TARGET								MIN	EXPT				
RANGE	500	600	700	800	900	1000	1300	1500	RD	RD	CD 90	CEP	HOB	PEH
2000	.96/.98	.93/.96	.85/.88	.51/.55	.41/.43	.29/.32	.21/.22	.09/.12	460	526	80	38	49	9
3000	.96/.98	.91/.96	.85/.97	.52/.56	.41/.43	.30/.32	.20/.22	.10/.12	458	532	93	44	59	12
4000	.96/.98	.91/.95	.85/.87	.53/.56	.41/.43	.30/.32	.20/.22	.10/.12	454	532	99	47	59	12
5000	.96/.98	.91/.95	84/.87	.53/.57	.41/.43	.30/.32	.20/.22	.10/.12	447	538	111	54	69	14
6000	.96/.98	.91/.95	.81/.86	.53/.57	.41/.43	.30/.32	.20/.22	.10/.12	448	540	128	62	82	17
7000	.95/.97	.91/.94	.80/.85	.55/.57	.41/.43	.30/.32	.20/.22	.10/.12	442	540	141	73	90	19
8000	.94/.96	.86/.92	.75/.83	.54/.57	.41/.43	.30/.32	.20/.22	.10/.12	434	538	176	86	101	22
9000	.92/.96	.78/.88	.68/.78	.53/.56	.37/.41	.28/.32	.20/.22	.08/.11	420	520	205	100	116	26
10000	.88/.94	.71/.85	.61/.75	.50/.55	.36/.40	.26/.31	.18/.21	.06/.11	400	490	234	115	132	30

Figure 3.5 Exposed Personnel, Latent Lethalities, SRC, 1 KT.

Entry arguments are the range (rounded up to the next highest listed value) and target radius. If the target radius is less than the first listed radius, then the first listed coverage is taken as the expected coverage. If the target radius is larger than the last listed radius then the weapon system is considered unsatisfactory. Otherwise, interpolation is performed on the radius and the resulting coverage is reported as the expected initial coverage.

EXAMPLE. If a short range cannon weapon was employed against personnel in the open with a target radius of 690 meters and the range to the target was 5200 meters the expected coverage would be 86.9%.

2. Numerical Method

When it is necessary to deliberately shoot at a target with an aim point other than the target center, the numerical method must be used. Fig. 3.6 was the chart designed for usage with expected coverage, but has been ruled invalid by USANCA. (Fig. 3.6 may still be used for expected coverage with no offset.) Therefore, when employing an offset aimpoint it is necessary to use the high assurance chart as shown in Fig. 3.7 which is used in the following discussion.

The numerical method has the following 6 steps.

1. Calculate RD divided by RT and locate on the left axis.
2. Calculate CD90 divided by RT and locate on the bottom axis.
3. The intersection of the values predicts the coverage without offset.
4. Calculate d divided by CD90 and locate on the left axis.
5. Measure the distance from the point located in 4 above to the line labeled "displaced DGZ d/CD90". This is refered to as the "measured distance".
6. Apply the "measured distance" to the right of the point found in 3 above. This final point predicts the coverage due to offset. It must also be remembered that this coverage has a 90% chance of occurring since the solution was found by using the high assurance table.

The following example is depicted in Fig. 3.7.

GIVEN:

RD = 600 meters CD90 = 100 meters

RT = 800 meters d = 300 meters

Find: The fractional coverage with the DGZ displaced.

Solution:

Step 1 RD/RT = .75

Step 2 CD90/RT = .125

Step 3 Initial coverage = .57

Step 4 d/CD90 = 3.0

Step 5 Measure distance

Step 6 Final coverage = .48

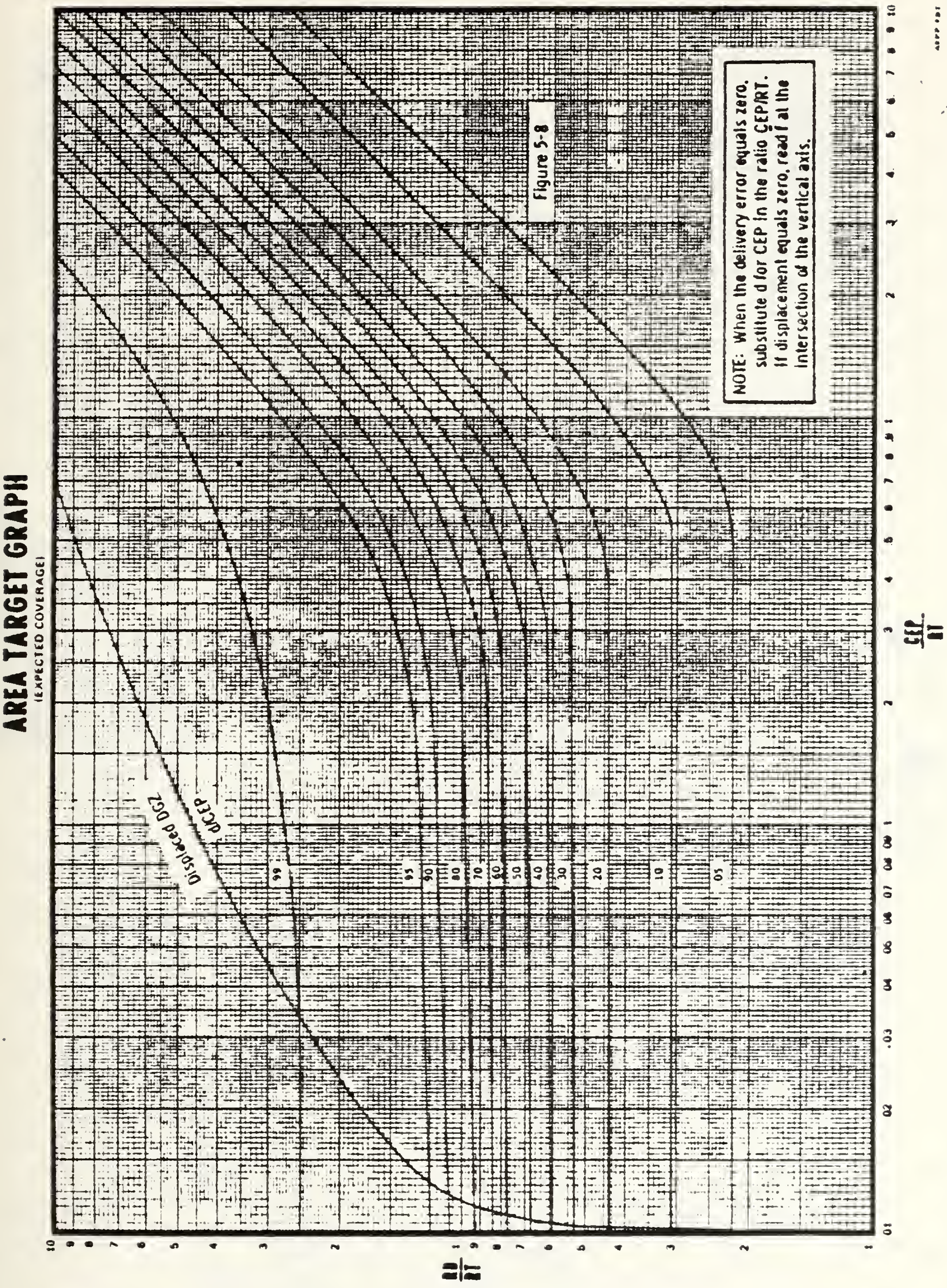

Figure 3.6 Area Target Graph (Expected Coverage).

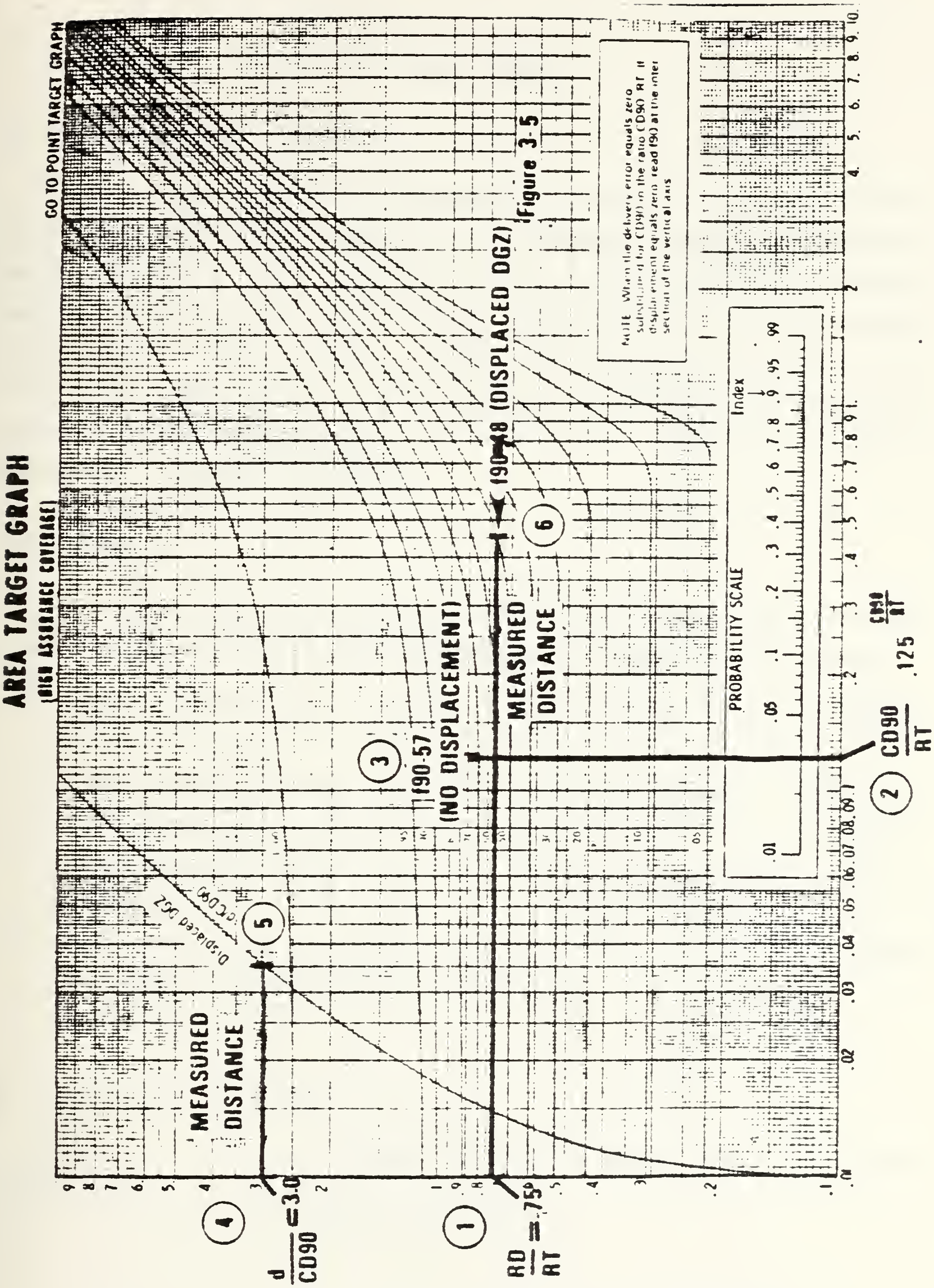

Figure 3.7 Area Target Graph (High Assurance).

IV. THE MODEL

A. INTRODUCTION

Before the model is invoked, a serious condition must exist on the battlefield - one in which the commander with responsibility and authority for employment of nuclear weapons has decided to use them. This decision must be made externally to the model. Once the decision is made, the model will make all of the decisions necessary to solve the target analysis problem, deliver the rounds and assess damages to target elements.

B. INPUT

As with any military operation, there are several essential elements of information which must be available.

1. The location and size of friendly maneuver elements must be known.
2. The location and type of nuclear capable artillery batteries along with their nuclear load must be known.
3. The location size and type of enemy targets must be estimated.
4. The commander's guidance for minimum acceptable damage to enemy units must be announced.

C. STEPS OF THE MODEL

Step 1. For each target select feasible battery/yield combinations.

A. Use the index method first.

B. If the index method provides adequate coverage, check for troop safety. If offset is not necessary, file as a solution.

C. If offset is required, use numerical method. If coverage is adequate, file as a solution.

D. Of all feasible solutions, select the one which provides maximum coverage.

Step 2. For each target, employ the best round.

Step 3. Assess damage for each target.

A. Assess damage to each tank.

1. Determine the distance from GZ where a tank has a 50% chance of damage due to overpressure.
2. Declare each tank as alive or dead as a result of a Monte Carlo draw.

B. Assess damage for each troop.

1. Determine the distances from GZ where a troop has a 50% chance of survival due to thermal radiation, overpressure and dynamic pressure.
2. For each troop in the target, perform a Monte Carlo draw for each of the above damage mechanisms. If any one fails, kill the troop.
3. For each troop in the target which survives to this point, determine nuclear radiation absorption. Place the troop in one of the 6 categories of;
   a. Dead
   b. Permanantely incapacitated.
   c. Temporarily incapacitated.
   d. Impaired.
   e. Latent impaired.
   f. Safe

To do all of this the model uses various routines and functions which are detailed in chapter V. The remainder of this chapter will explain how the model proceeds, what assumptions are made and, in a few cases, where some simplifying approximations are made.

D. SELECT FEASIBLE BATTERY/YIELD COMBINATIONS

The model loops through every target with every possible battery/yield combination in an attempt to compile a listing of adequate solutions. The proceedure is to;

1. Use the index method.
2. Determine if offset is necessary.
3. Use numerical method if offset is necessary
4. If coverage is adequate, file as a feasible solution.

1. Index Method

To start, the range to the target is computed. If it is farther than the maximum range of the weapon system currently being looped through, then it cannot be engaged by that battery. The model will now loop to the next battery.

Technically, a target which is out of range may still be attacked successfully. In this situation an offset distance equal to the difference between the actual range and the maximum weapon range is used in a numerical method analysis. The model does not allow for such an occurrance.

If the target is within range, the model loops through each yield of the weapon system. Starting with the smallest yield, the target radius is compared to the maximum table target radius. If it is too large, then the model loops to the next higher yield. If it is not too large, it performs an index method analysis.

Should the index method analysis provide a coverage which is equal to or greater than the command guidance for the target type, then a potential solution has been found. If the coverage is inadequate, then the model loops to the next higher yield.

It must be remembered that the target/battery/yield sequence is a nested loop and it may not always be possible to loop to the next higher yield. At a time when the highest yield for a weapon is being looped over, looping to the next higher yield actually means looping to the next battery and starting again with the lowest yield. The same applies to looping to the next battery when the model is at the last battery.

Whenever a feasible solution is found with the index method, the target is immediately checked for necessary offset. Thus the loop in temporairly interrupted in order to check for possible offset.

2. Offsetting Desired Ground Zero

Recall that the index method required the desired GZ to be the center of the target. Any offset necessitated by troop safety considerations would require the use of the numerical method which would analyze the target as a high priority target and result in a degraded coverage. In the case where initial coverage was adequate, further analysis must be done to see if offset is required and what effect on feasability it has.

To perform an offset is easily done on a map with a compass, but is not as easily done with a digital computer. Fig. 4.1 shows how it is done manually. The method is to draw circles about each friendly maneuver unit center. The radius of each circle is the unit radius plus the minimum separation distance (MSD) to insure troop safety. The desired ground zero must lie outside each circle. The

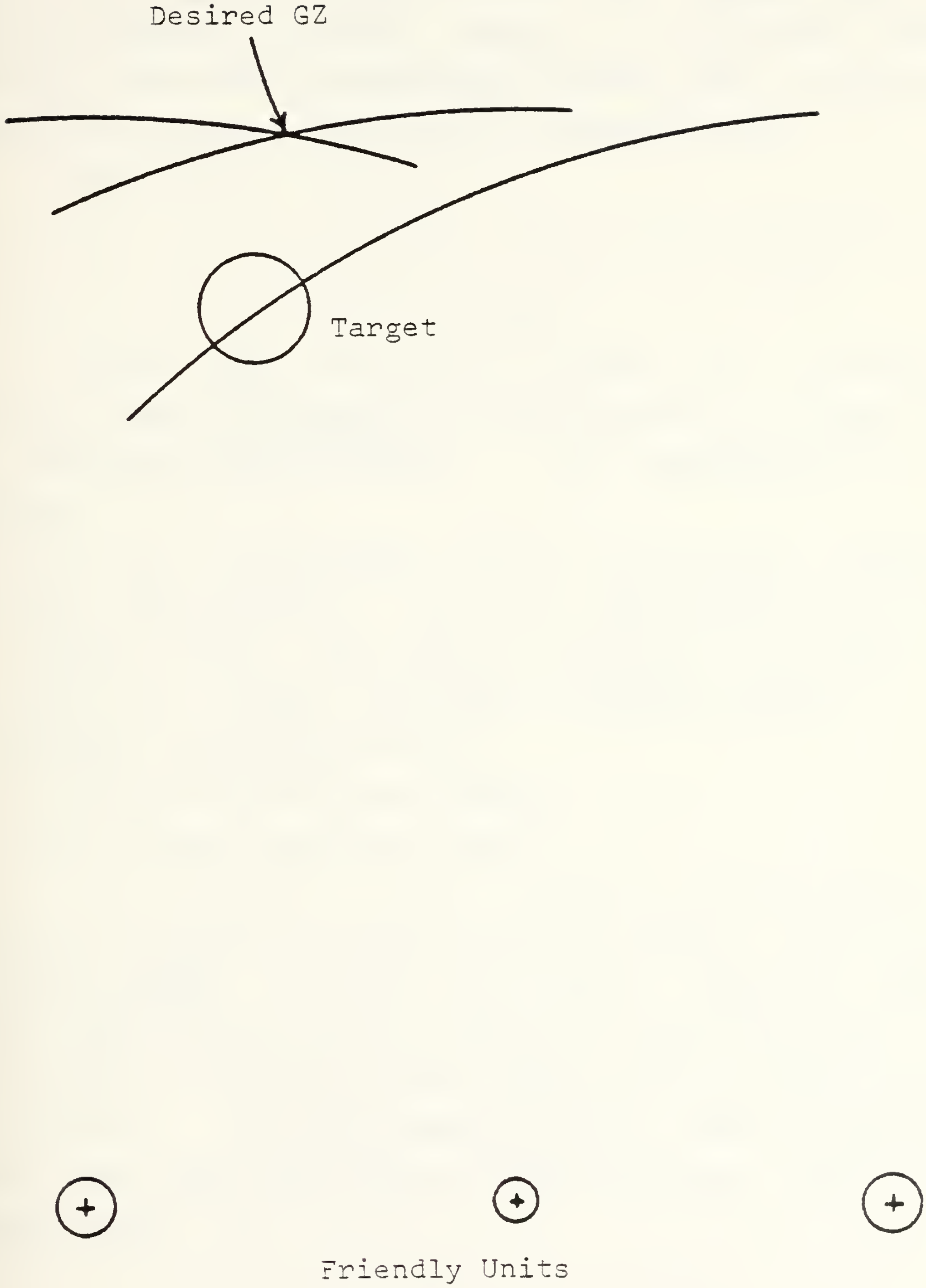

Figure 4.1 Manual Solution to Offset Problem.

chosen aim point is the point on the map which is closest to the target center and still exterior to every circle.

Simply stated, one just gets as close to the target center as possible while staying far enough from each friendly element to ensure safety. To do this envolves solving a non-linear programming problem with a non-convex feasability region. The problem formulation is;

$$\text{MIN } (X-X_T)^2 + (Y-Y_T)^2$$

$$\text{st. } (X-X_i)^2 + (Y-Y_i)^2 \geq (\text{MSD} + \text{Unit Radius}_i)^2$$

$$i = 1, \cdot \cdot \cdot , \text{No. of Units}$$

Rather than solve that problem, it is easier to solve an iterative geometric approximation. In many cases the approximation is exact. The approximation is as follows.

1. Find the friendly unit whose perimeter is closest to the target center. If it is within MSD of the target center, move the desired ground zero directly away from it an amount necessary to satisfy safety.
2. Repeat the process until;
   A. No unit lies within MSD or
   B. 10 steps have been tried.

If a solution cannot be found in 10 steps it is probably because no feasible solution exists. Fig. 4.2 is a typical example. Of the five units, three of them lie within MSD and the desired ground zero must be moved. Unit 4 is closest and the desired ground zero is moved directly away from it. The new desired ground zero is acceptable. It is also exact and not an approximation. This is the typical case.

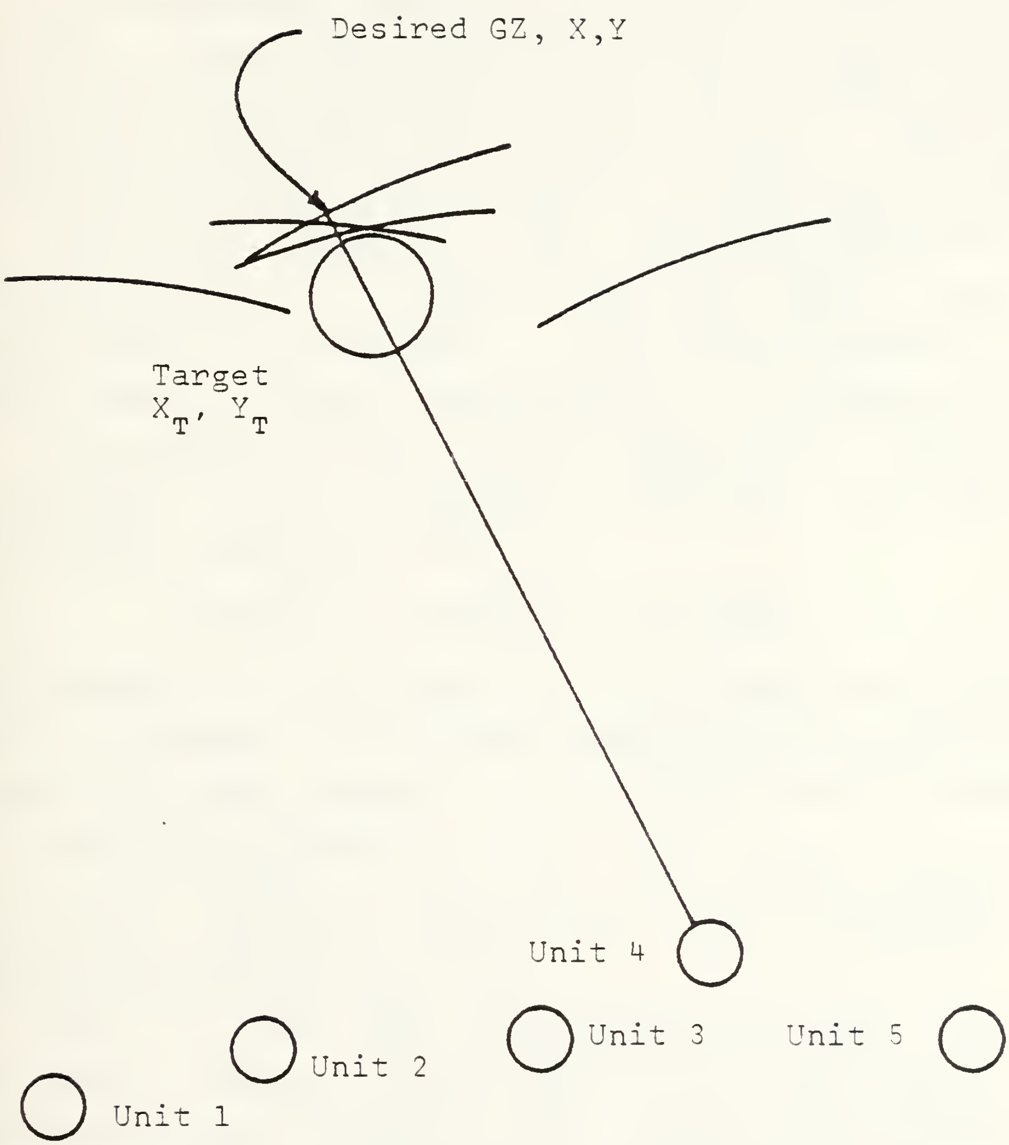

Figure 4.2 A Geometric Solution.

If unit 2 moves forward as shown in Fig. 4.3, the solution requires two iterations and is now an approximation. The first iteration moves the desired ground zero to position 1. However, unit 2 is within MSD and desired ground zero must be moved again. This time position 2 is selected. It is feasible and close to the optimum location.

3. <u>Numerical Method</u>

The numerical method was discussed in Chapter III, Section C-2. This method was developed for use by a nuclear target analyst in a field environment using tools commonly available in a Divisional Fire Support Element. Such tools are FM 101-31-3 [Ref. 2], a compass, dividers and a pencil. Thus, the transposition of the "measured distance" and reading of a point on a graph seem like simple tasks and natural things to do manually. The method followed in the computer code is a slight modification of the manual method.

The scales in Fig. 3.7 are logrithmic. Therefore, the addition of the "measured distance" is really a multiplication operation such as;

CD90/RT <-- CD90/RT * f(d/CD90)

where f(d/CD90) is the appropriate multiplier and is only a function of d/CD90. It is much more reliable in the field to allow the target analyst to use dividers than to require him to correctly multiply.

In the example on page 39, the initial CD90/RT was .125 and the displaced CD90/RT was .450. Obviously the appropriate multiplier was 3.60.

Fig. 3.7 has been included here as Fig. 4.4 with point number 7 added. If the value of the point number 7 is multiplied by 100, it will be 3.60. Thus, the appropriate multiplier can be found directly from the figure without any

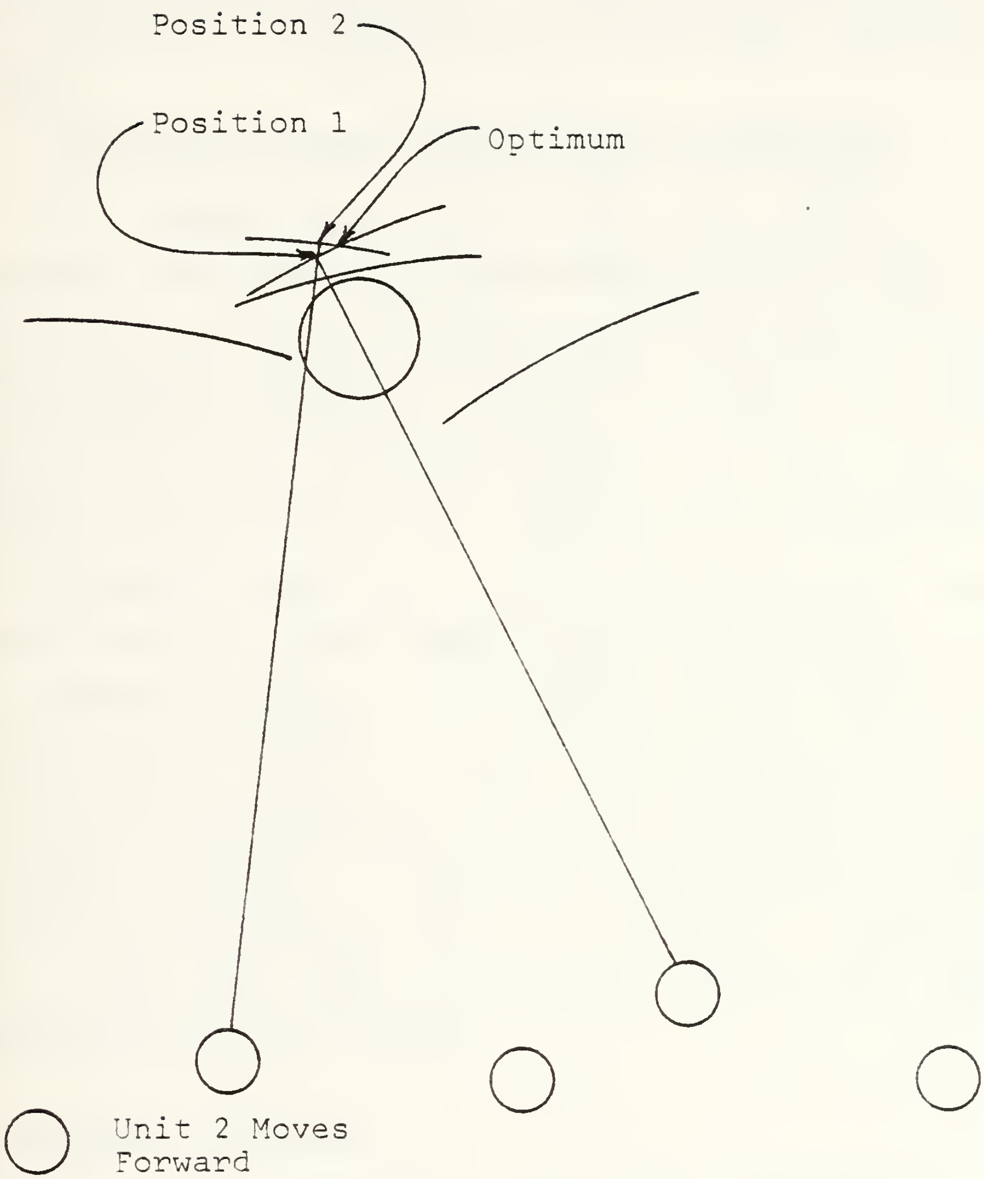

Figure 4.3 Offset as an Approximation.

further modification. Several points on the d/CD90 scale and the corresponding f(d/CD90) are in the data base. For any d/CD90 the correct f(d/CD90) can be found with one interpolation.

The coverages from Fig. 3.7 are input into the data base as a 2-dimensional table. Thus with RD/RT and CD90/RT known, a double interpolation will produce the predicted coverage.

4. Choosing the Best Battery/Yield Combination

If, after all of this work, the coverage is now inadequate, the solution is abandoned and the program moves on. However, if it is adequate, a solution containing the target, battery, yield, desired GZ and predicted coverage can be generated and filed away for later use. It would be useful to file the feasible solution in such a way that recovery of the top one on the list is the best solution.

Table III shows hypothetical results of an analysis requiring offset for the rounds of the MRC battery. Due to safety imposed offset, the largest yield, while still meeting command guidance, is clearly not the best choice. In fact, neither of the rounds from the MRC battery is the best choice. The SRC battery with a 1 KT yield will provide the highest coverage. Therefore, this program will file solutions in descending order of coverage. Should a tie occur, the SRC takes precedence over the MRC for conservation of force reasons.

E. EMPLOYING THE ROUND

When all of the targets have been analyzed for each battery, the target analysis portion of the model is finished. It is time to select the best battery/yield combination, employ the weapon and assess damage. Actual

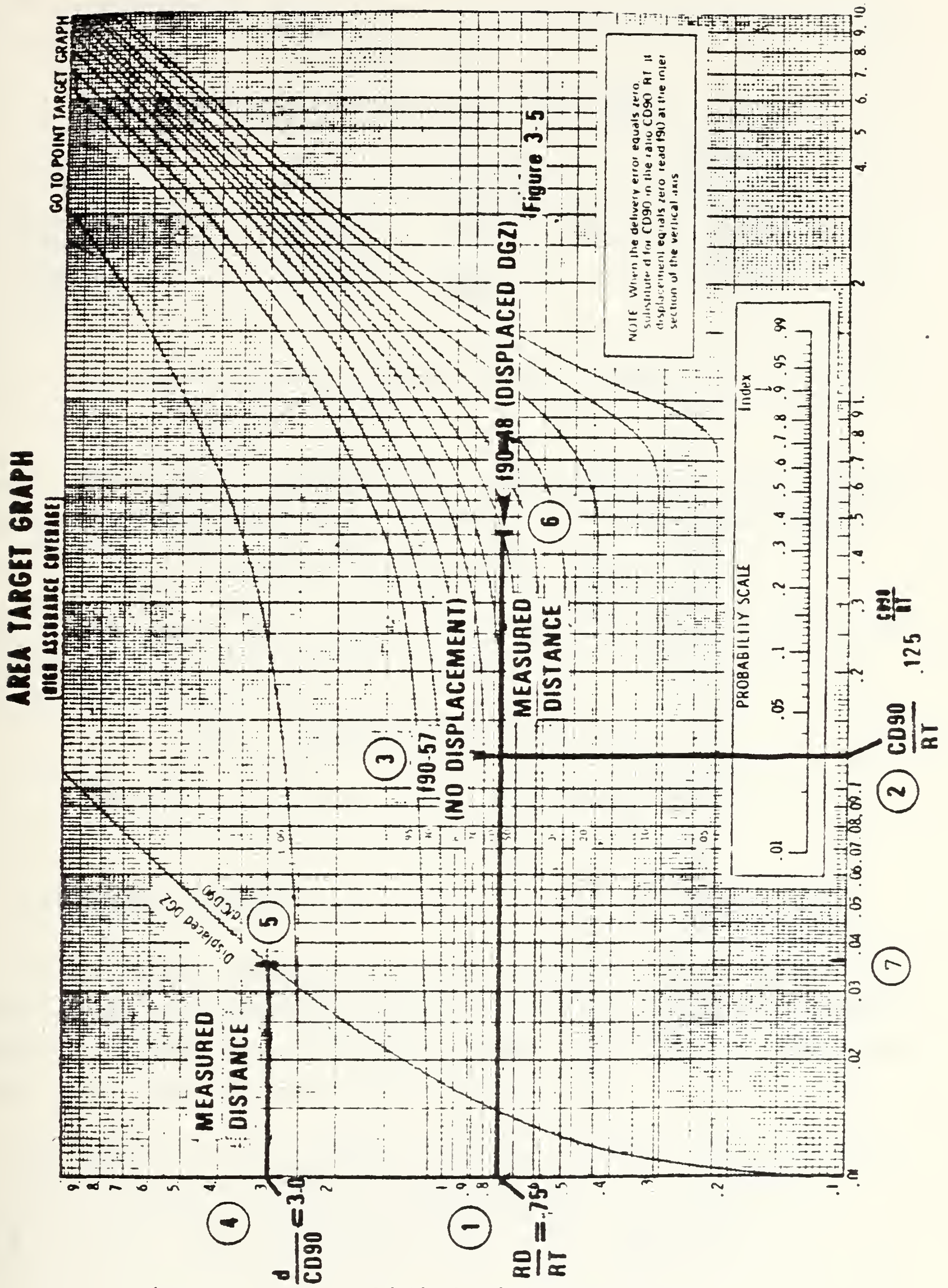

Figure 4.4   Modified High Assurance.

TABLE III

Degraded Coverage Due to Offset

Battery Type		Initial coverage	Offset coverage
Short Range	.2 Kt	41%	41%
Cannon	1 KT	78%	78%
Medium Range	2 KT	82%	73%
Cannon	8 KT	97%	44%

burst parameters are normally distributed. The actual ground zero is picked from a bivariate normal distribution.

$$GZ = N(\text{desired ground zero, CEP}/1.1774)$$

Hieght of burst and yield are selected from univariate normal distributions.

$$HOB = N(\text{desired HOB, PEH}/.67)$$

$$\text{Yield} = N(\text{nominal yield, nominal yield}/10)$$

F. ASSESSING DAMAGE

For damage assessment it is assumed that HOBopt was selected as though overpressure was the governing effect. This is done to avoid reading Figs. 2.1 and 2.2 into the data base. This is done for two reasons.

1. The data in the figures is very coarse and should not be accepted as highly accurate [Ref. 1: preface].
2. A linear function results from the assumption.

If the assumption that the weapon will function at HOBopt for overpressure is made, then one variable, the HOB, can be omitted. If the employed weapon functions at HOBopt then the scaled HOB is simply the HOBopt for a 1 KT weapon.

Using this HOB and the ranges found in Fig. 2.1 for desired overpressures and in Fig. 2.2 for desired dynamic pressures, it is possible to plot yield against range with pressure as a parameter. Figs. 4.5 and 4.6 show these results.

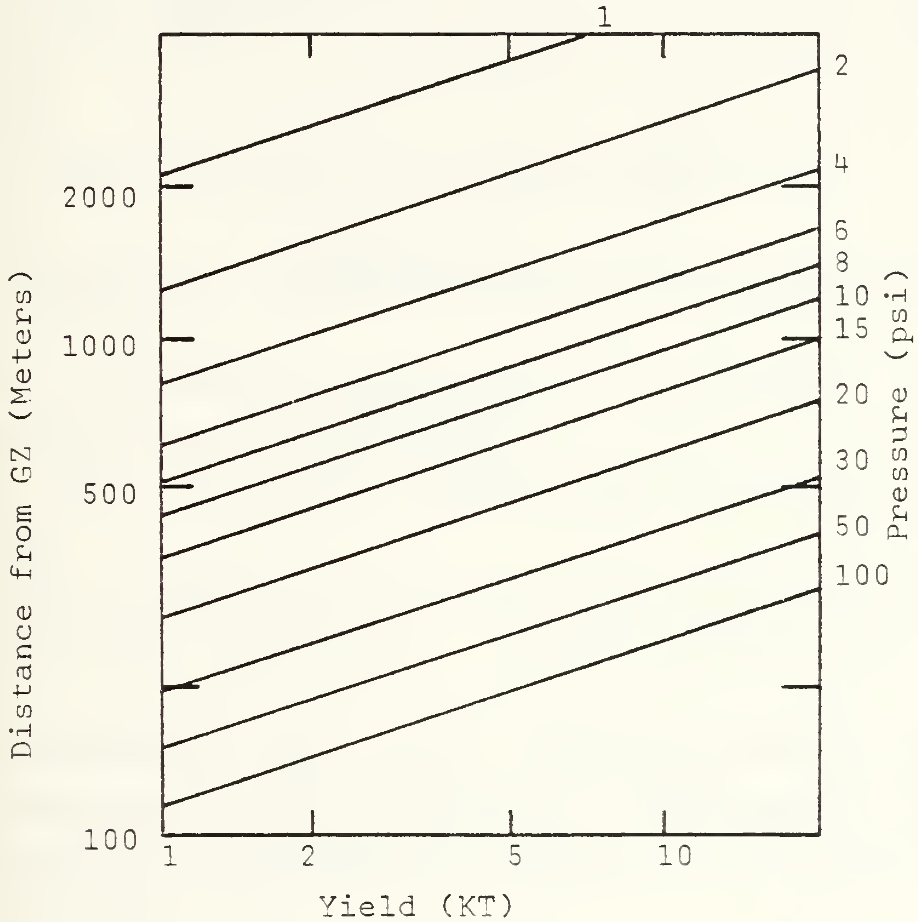

Figure 4.5 Overpressure from Optimum HOB.

If the weapon yield and the required overpressure or dynamic pressure for a particular target defeat is known, it is a simple matter for the computer to calculate the range at which defeat will occur. An example will demonstrate this.

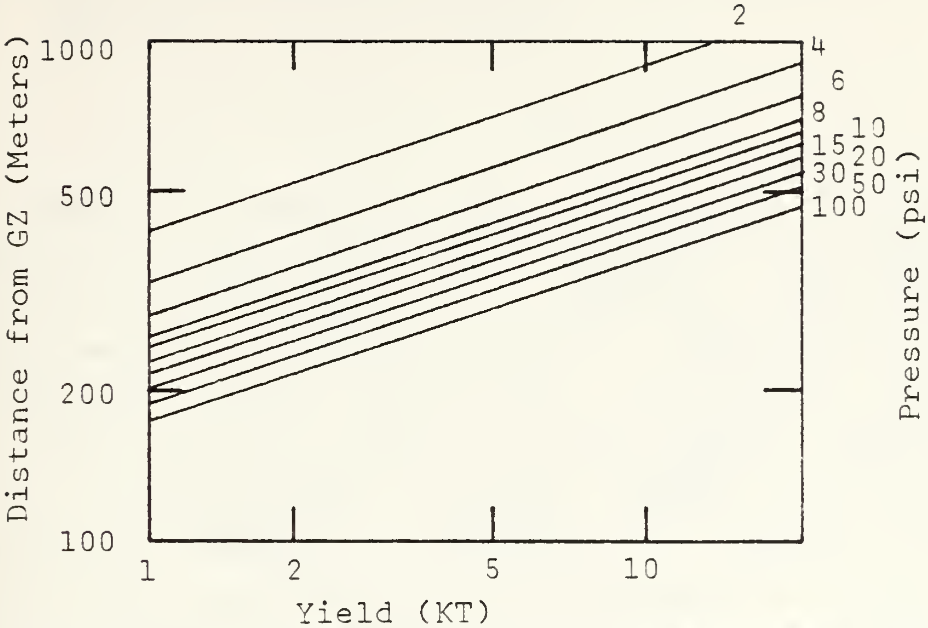

Figure 4.6 Dynamic Pressure from Optimum HOB.

Given: A detonation results in a 10 KT yield. An APC is damaged by 15 psi overpressure.

Find: The distance from ground zero at which the APC is damaged.

Solution: From Fig. 4.5 locate 10 KT on the lower scale. Go up to the 15 psi line. Read 790 meters from the left scale.

In the model, Eq. 4.1 is used to determine the range. The coefficient A is a function of overpressure or dynamic pressure and is determined from Figs. 4.5 and 4.6 when the yield is 1 KT.

$$RD = A \cdot Yield^{1/3} \quad (4.1)$$

The same simplification can be made concerning arrival time. Equation 4.2 is the result.

$$T = \{(.0028 \cdot R) - .45\} \cdot Yield^{1/3} \qquad (4.2)$$

It must be pointed out that this method will predict a larger RD for overpressure than is correct when overpressure is not the governing effect. However, overpressure is almost always the governing effect. (Radiation is usually the governing effect only against personnel in the open.) But, when radiation is the governing effect, enhancing the effects of overpressure to their optimum will still not outweigh the effects of radiation. A soldier killed by radiation will still be killed by radiation. The only error is that a soldier who survives radiation and should have survived overpressure will now have a decreased chance of survival.

The alternative to the simplified method is to revert to Eq. 2.1 with a table look-up and 2 way interpolation.

G. VARIABILITY OF EFFECTS

An object positioned at a certain range from a given yield will be subjected to overpressure, dynamic pressure, thermal radiation and nuclear radiation. In many cases one damage mechanism will dominate the others. It would be a simple matter to use only the dominant mechanism in determining damage. In an expected value model this technique is entirely justified but such a proceedure is not followed in this model.

In a probabilistic model, such as this one it is entirely possible for a target element to "beat the odds" on overpressure and be killed by secondary missiles brought about by dynamic pressure. If there was a 75% chance of

damage by overpressure and only a 10% chance of damage by dynamic pressure in a 50% threshold model, the element would be killed by overpressure every time. In this model, each mechanism gets a Monte Carlo chance to cause damage. In the above example the subject has a 77.5% chance of damage. More importantly, it has a non-zero chance of survival.

If the RD from Fig. 4.5 is found to be 700 meters (10 psi and 10 KT) then what are the probabilities for survival at a closer range and for damage at a farther range? The expected value model would set these probabilities at zero. This model will allow survival at a closer range and damage at a farther range. To do this requires a probability distribution.

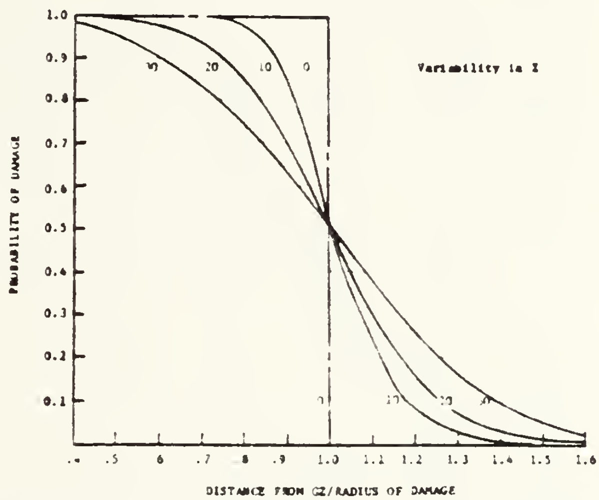

Figure 4.7 Variability of Effects.

Fig. 4.7 [Ref. 4: p. D-3] is used in the FM 101-31 series and is followed in this model. The 20% variance curve is the one which is used. Plotted on normal plotting paper, it looks like Fig. 4.8.

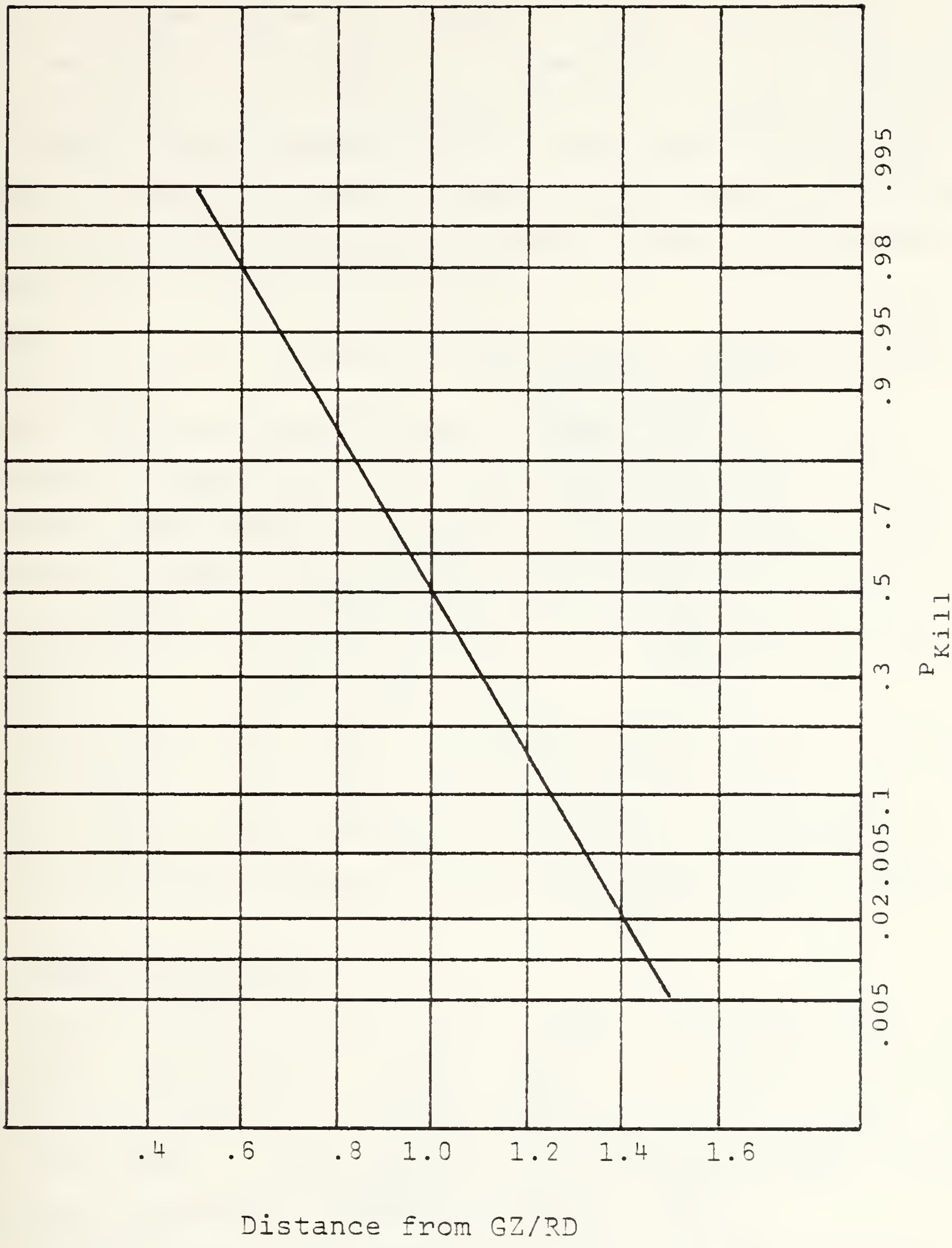

Figure 4.8 Standard Deviation is 20% of R/RD.

According to Fig. 4.7, a target element at ground zero has some finite chance of survival while an element at an infinite range may still perish. This is a logical result of the normal probability assumption. To approximate reality, any element with less than 0.5% chance of survival is killed while anything with more than 99.5% chance of survival always survives. Thus, only when R/RD is between .5 and 1.5 is the Monte Carlo chance taken. An example will demonstrate how the method works.

GIVEN: A 6 KT burst. Tanks are damaged by 20 psi overpressure.

FIND: Damage to tanks at 200 and 900 meters from GZ.

SOLUTION: From Fig. 4.5 the range at which a tank is damaged is 500 meters. Correctly stated, this is RD, the distance at which the tank has a 50% chance of survival The first tank has a distance/RD of .40. From Fig. 4.8, the probability of survival is less than 0.5% and the tank is killed.

The second tank has a distance/RD of .555. A uniform (0,1) draw is made for the tank and the number of .60 is drawn. Since .555 is less than .60, the tank survives. Had .554 or less been drawn, the tank would have been killed.

H. TARGET RESPONSES

Target elements are of two types - tanks and personnel. However, any target element which is damaged by blast, thermal radiation or nuclear radiation may be easily input into the model. Such elements would include APC's, trucks, buildings, aircraft, forests, bridges, etc.

In this model the tanks are either fully functional or killed. Personnel may have an additional state - dying. This is caused by the absorption of nuclear radiation. While the various mechanisms may kill a soldier upon burst,

only the nuclear radiation will cause a latent, lingering death. Fig. 4.9 [Ref. 4: p. C-9] is used to classify radiation casualties into the states of:

1. Dead.
2. Incapacitated and dying.
3. Impaired and dying.
4. Safe and fully functional.

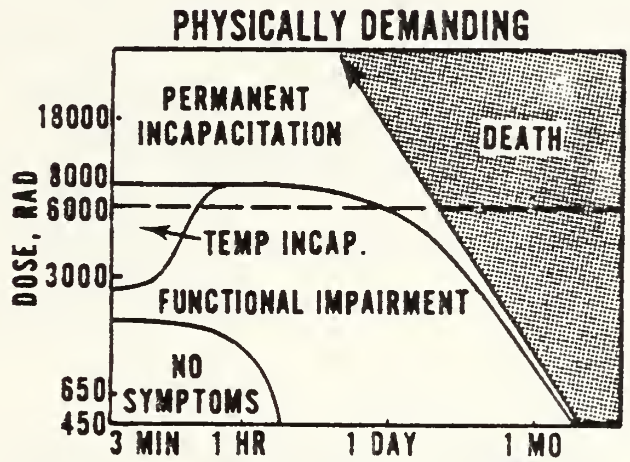

Figure 4.9 Personnel Responses to Radiation.

The model simplifies Fig. 4.9 into Fig. 4.10 with the following:

1. Anyone receiving 18,000 rads is declared dead immediately.
2. Anyone receiving 8,000 to 18,000 rads is immediately and permanantly incapacitated. He cannot shoot, move or communicate but is still alive and should be considered a potential target.
3. Anyone receiving 3,000 to 8,000 rads is immediately incapacitated but in time is upgraded to functionally impaired. The time is uniformly distributed from 30 to

45 minutes. Eventually the person dies. Death occurs in a uniformly distributed amount of time from 2 to 5 days.

4. Anyone receiving 2,000 to 3,000 rads is immediately placed in the functionally impaired state where he remains until death occurs in 2 to 5 days.
5. Anyone receiving a dose greater than his own personal lethal limit but less than 2,000 rads is unaffected until some latent period has passed at which time he becomes functionally impaired. This time is uniformly distributed from 30 to 60 minutes. Eventually, the person dies in 2 to 5 days. The lethal limit is normally distributed about 650 rads with a standard deviation of 50 rads.
6. Anyone receiving less than his own personal lethal limit is unaffected.

I. OUTPUT

When the model is completely finished it will print all of the pertinent information concerning each target and employed round. Final output will be;

1. Burst parameters of GZ, HOB and yield for destruction of each target.
2. Location and disposition of each element in each target. For personnel not immediately killed, the incapacitation and/or impairment times will be listed as appropriate.

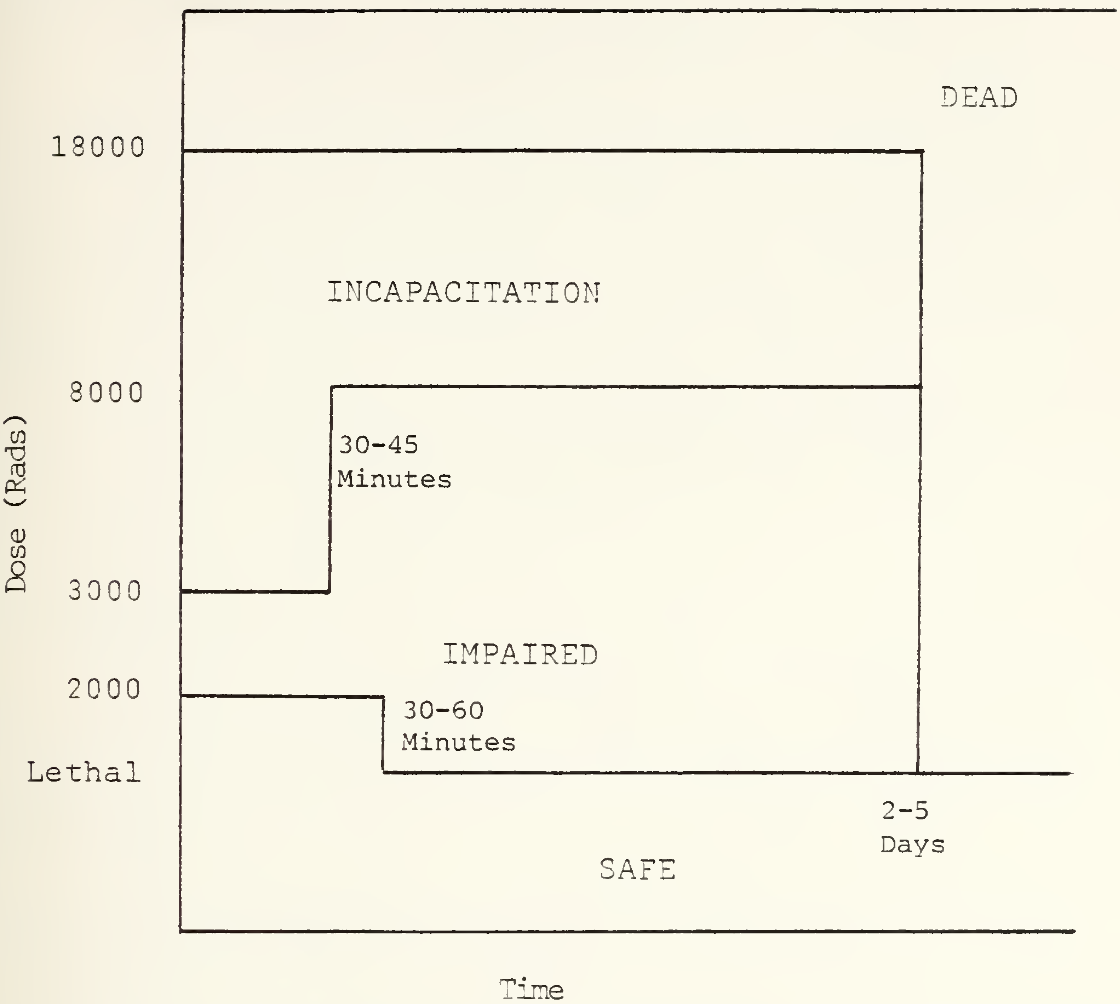

Figure 4.10 Simplified Personnel Responses to Radiation.

J. SUMMARY

This model will, given several nuclear capable artillery batteries, friendly locations and enemy locations, select optimum choices of batteries and yields to fire at each enemy target. It will, when necessary, allow for troop safety by offsetting the aim point of the weapon. It will simulate delivery of each round and stochastically assess damage to each individual element within the target. Tanks

will be declared either alive or dead while personnel will be allowed a dynamic transition from living to dead due to nuclear radiation.

V. MODEL ROUTINES

This chapter will explain the important sections of the actual model in detail. Actual lines of the SIMSCRIPT model (printed in capital letters) will be presented followed by an explanation of what they do or mean. The complete model is included as Appendix B. Each routine and function is discussed as a sepatate section in this chapter.

In reading about each routine and function it may be helpful to refer to Fig. 5.1 to keep the flow of the model in order.

A. PREAMBLE

The preamble extablishes global variables, identifies permanent and temporary entities and their attributes, groups entities into sets and identifies user defined functions.

```
PERMANENT ENTITIES
  EVERY BATTERY HAS A SIZE, AN XB, A YB AND SOME NUC.ROUNDS
  EVERY COMPANY HAS A XC, A YC, A ZC AND A CO.RADIUS
  EVERY TARGET HAS A TYPE, A XT, A YT, A ZT, A RT
        AND MAY OWN A TANK.SET, A TROOP.SET, AND A LISTING
```

The BATTERY is an entity representing a nuclear capable artillery battery. The SIZE is either short range cannon (155mm, SIZE = 1) or medium range cannon (8 in., SIZE = 2). XB and YB are grid coordinates. NUC.ROUNDS is the quantity of nuclear rounds the BATTERY has available to fire.

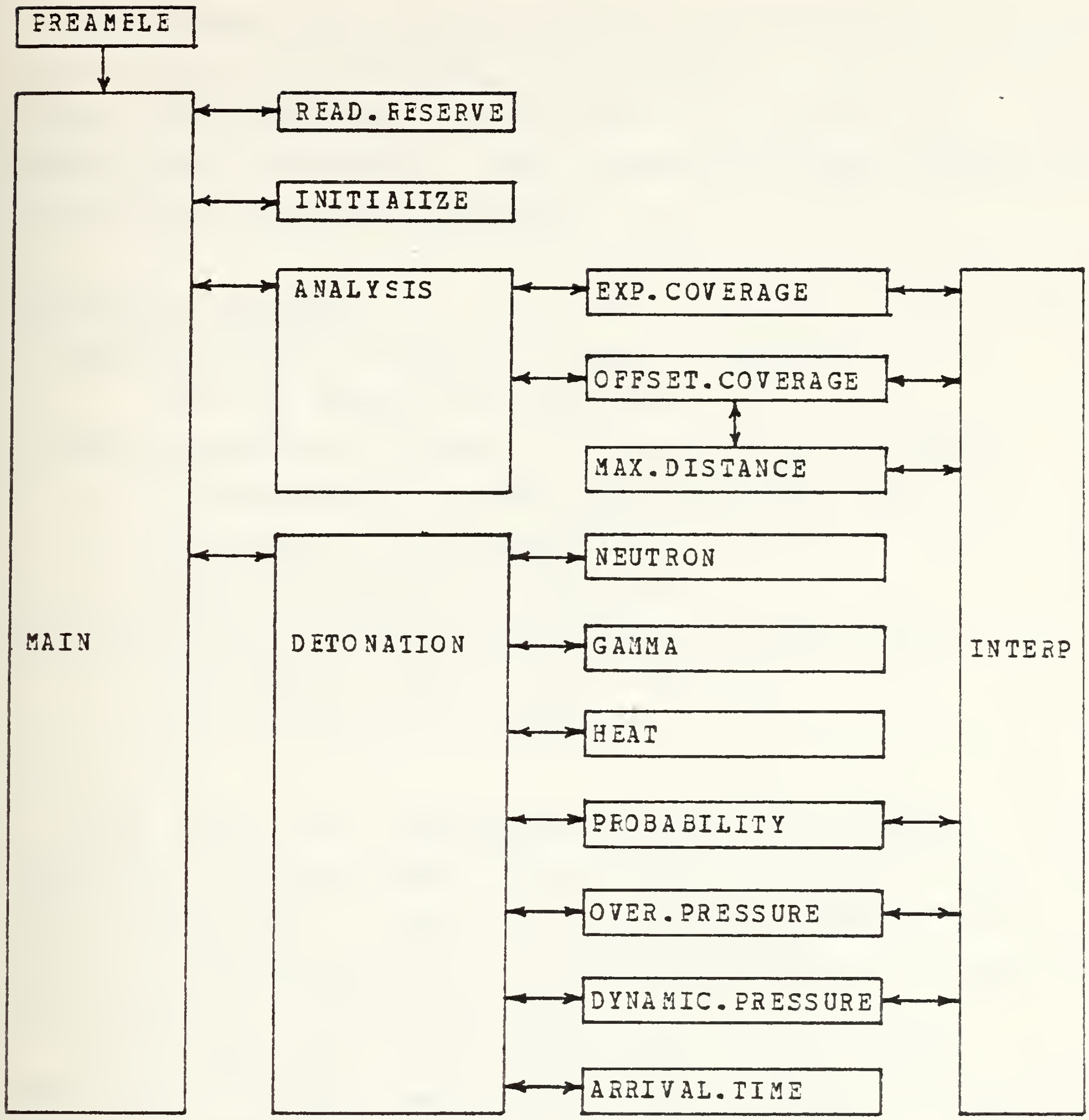

Figure 5.1 Routine/Function Routing Chart.

The COMPANY is an entity representing a friendly unit. It may be an individual soldier or vehicle or a collection of such. Its reason for existing is to cause offset targeting due to friendly safety constraints. XC, YC, ZC are the grid coordinates and altitude. CO.RADIUS is the radius of the unit.

The TARGET is an entity which is to be attacked. XT, YT and ZT are grid coordinates and altitude. RT is the target radius or equivalent as explained in Chapter III. The TARGET owns three sets. They are sets of TANKS, TROOPS and a LISTING of feasible SOLUTIONS.

```
TEMPORARY ENTITIES
  EVERY TANK HAS A X.TANK, A Y.TANK, A TANK.DEAD,
       AND MAY BELONG TO A TANK.SET
  EVERY TROOP HAS A X.TROOP, A Y.TROOP, A TRANS.FACTOR,
       A TROOP.DEAD, A LETHAL.DOSE, AN ACCUM.DOSE,
       A T.LETH, A T.IMPAIR.NUC
       AND MAY BELONG TO A TROOP.SET
  EVERY SOLUTION HAS A UNIT.TO.FIRE, AN XDGZ, A YDGZ,
       AN IYIELD, A JROW, A KCOL AND A PCT
       AND BELONGS TO A LISTING
```

The TANK has coordinates X.TANK and Y.TANK. The altitude is assumed equal to that of the target to which it will be assigned. TANK.DEAD is an integer number, either 0 or 3. A 0 means the tank is fully functional. A 3 means it has suffered a catastrophic kill.

The TROOP has coordinates X.TROOP and Y.TROOP. The altitude is assumed equal to that of the target to which it will be assigned. The TRANS.FACTOR is the radiation transmission factor and is currently either a 1 for exposed, .3 for protection inside an APC and .001 for a fox hole. TROOP.DEAD is similar to TANK.DEAD except for two additional values. A 1 is functionally impaired and a 2 is incapacitated. LETHAL.DOSE is that radiation dose above which the TROOP will eventually die. ACCUM.DOSE is the radiation dose the TROOP has currently accumulated. T.LETH is the time when TROOP.DEAD is to be set equal to 3.

T.IMPAIR.NUC is the time when TROOP.DEAD is to be set equal to 1.

A SOLUTION is an answer to the nuclear target analysis problem. Its attributes are the firing unit, desired ground zero, expected coverage and indicies to locate the table, row and column where the solution was found. It is filed in a LISTING belonging to a TARGET. The LISTING is ranked first by high coverage and then by low yield.

GLOBAL VARIABLES

There are two sets of equivalent arrays. One pertains to the SRC and the other to the MRC. The SRC has 9 rows while the MRC has 19 rows. In the following, only the SRC is explained but the description extends equally to the MRC.

SRC.P.COVERAGE is the 4 dimensional matrix which contains the coverage probabilities. The first subscript is the yield. The second is the type of target. The third and fourth are the row and column of the table described by yield and type. The current model allows seven types of targets. They are;

1. Exposed personnel. Immediate permanent casualties.
2. Exposed personnel. Immediate transient casualties.
3. Personnel in fox holes. Immediate permanent casualties.
4. Personnel in fox holes. Immediate transient casualties.
5. Moderate damage to Tanks.
6. Moderate damage to Wheeled Vehicles.
7. Moderate damage to Artillery.

SRC.RANGES is the array of ranges that the system is capable of. (See Fig. 3.5)

SRC.TABLE.RT is the 3-dimensional matrix which contains the RT for the various tables. The first subscript is the yield. The second is the type of target. The third is the column of the table. (See Fig 3.5)

SRC.YIELDS is the array of possible yields. Each weapon has two yields available. The SRC has a .2 KT and a 1KT while the MRC has a 2 KT and an 8 KT.

MSD.SRC is a 2-dimensional matrix which contains values of minimum safe distances. The first subscript is the row of the table and the second is the yield. MSD is only a function of weapon size, range and yield but not target type or degree of damage.

CD90.SRC, CEP.SRC and PEH.SRC are arrays with only the range as a variable. They are a function of the delivery system only. The subscript is the row of any table for the applicable weapon system.

HOB.SRC is a 3-dimensional matrix which has the desired height of burst. The first subscript is the yield. The second subscript is the row of the table. The third subscript is the type of target.

SRC.MIN.RD and SRC.EXP.RD are the minimum radius of damage and the expected radius of damage. Their dimensionality and subscript meaning are the same as HOB.SRC.

CD90.RT, RD.RT, D.CD90 and DISPLACED.COVERAGE are the parameters used with Fig. 3.7 to solve an offset coverage problem. CD90.RT is CD90/RT. RD.RT is RD/RT. D.CD90 is d/CD90. DISPLACED COVERAGE is a matrix of coverage values used for table look-up once the entry arguments have been determined.

B. MAIN

The MAIN serves as a vehicle to define and read local variables and call subroutines and functions which do the bulk of the work.

POLICY is an array which represents the commander's guidance on each of the types of targets. Its length is NTABLES - one for each of the seven types of targets. If the predicted coverage on a target does not equal or exceed the POLICY for that type of target, then the solution is abandoned.

RANGE is the range from the battery to the target for which a solution is being sought.

The remainder of MAIN is involved with calling subroutines to solve the problem. MAIN first calls READ.RESERVE which reserves and reads all of the global variables. MAIN then calls INITIALIZE. It then loops through every TARGET and every BATTERY in an attempt to find adequate SOLUTIONS. To do this it calls ANALYSIS which, in turn, calls other subprograms. After returning from ANALYSIS, the MAIN is ready to employ the weapons. It removes the first SOLUTION from the LISTING of each TARGET and calls DETONATION which assesses damage. Upon returning from DETONATION, the MAIN lists the attributes of the permanent entities and terminates.

C. SUBROUTINE READ.RESERVE

This subroutine reserves and reads the global variables as defined in the PREAMBLE

D. SUBROUTINE INITIALIZE

This is a surrogate for a driver program. As stated in the abstract, this program is intended as a subroutine for a larger simulation - one which already has entities such as TARGET, TANK and TROOP. Since these entities do not exist, INITIALIZE creates them. A detailed description of the subroutine will not be offered here since it is unimportant and easy to read. It will suffice to say that it uniformly

distributes TANK and TROOP entities within the RT of the TARGET while assigning attributes to the temporary entities.

E. SUBROUTINE ANALYSIS

This subroutine is the origin of SOLUTION. It is here that a decision is made to create a SOLUTION and then to file it in a LISTING or discard it. The first action is to determine the size of the BATTERY which has been passed to it. It then determines if the TARGET is within range. If not, it returns to MAIN without a SOLUTION. If the range is less than the maximum weapon range, then it finds the proper row (J) to use as an entry argument. It then loops over all yields to determine coverage for each yield. For each yield it determines the proper column (K) to use as the other entry argument. If it cannot find any (RT too big) it loops to the next yield or returns to MAIN if it was at the largest yield.

If a row and column were found, then a SOLUTION is created and the index method is used to compute the initial coverage. If the RT is less than or equal to the first listed in the table, then the coverage in the first column is reported. If not, the function EXP.COVERAGE is called. This returns the expected initial coverage using the index method.

A decision is made concerning the coverage and the command guidance (POLICY) for that type of target. If the coverage is adequate, then OFFSET.COVERAGE is called. This will return with a new coverage which is less than or equal to the one returned by EXP.COVERAGE. If this new coverage is still adequate, the attributes of SOLUTION are determined and it is filed in the LISTING of the TARGET for which it was called. Control is then returned to MAIN.

F. SUBROUTINE EXP.COVERAGE

This function was originally established to perform the interpolation with the index method. However, as it became necessary to perform interpolation in other subprograms, a dedicated interpolation function (INTERP) was written. Currently this function simply determines the size of the BATTERY and properly formats the arguments for a call to INTERP. It then returns with the expected coverage to ANALYSIS.

G. SUBROUTINE OFFSET.COVERAGE

This subroutine is called when the initial analysis is at least adequate. It determines if any offset is necessary and, if so, performs an analysis using the numerical method.

The first order of business is to call MAX.DISTANCE which actually locates the new desired ground zero. If there is no displacement, then there is no change in coverage and control is returned to ANALYSIS. MAX.DISTANCE will also return a flag which may mean no feasible solution exists and coverage is set equal to zero. This will cause the solution not to be filed in a LISTING.

Next, the battery size is determined and the entry arguments of Fig. 3.7 are calculated. Depending on the value of d/CD90 (Y2) one of three things can happen;

1. Consider the target as a point target.
2. Analyze as instructed.
3. Degradation is insignificant. Return.

Currently, a point target analytical technique is not included, but the technique is slightly easier than this one. The only time an area target would be analyzed as a point target is if the RD is at least 10 times greater than RT. This only happens with large yields. Case 2 is the

only one for which further analysis is required (assuming case 1 does not happen).

Case 2. d/CD90 is located on the ordinate and (with a call to INTERP) the measured distance is found. As explained in Chapter III, the measured distance (DELX) is multiplied by the original CD90/RT and used to find the predicted coverage due to offset. A double interpolation is necessary to find the coverage. Control is then returned to ANALYSIS. If the coverage is still adequate, the SOLUTION is filed in a LISTING.

H. FUNCTION INTERP

This is an elementary interpolation function, is self explanatory and is not further explained here.

I. SUBROUTINE MAX.DISTANCE

This subroutine performs the approximation to the non-linear programming problem as stated in Chapter III. The logic follows the graphical solutions as shown in Figs. 4.1 and 4.2

J. SUBROUTINE DETONATION

The purpose of this subroutine is to assess damage now that the analysis is complete. The best SOLUTION for a TARGET has been removed from its LISTING and passed to this subroutine.

Again, a decision is made regarding the BATTERY size. The standard deviation for ground zero location is found Eq 3.1. The PEH and desired HOB are selected from the tables.

To determine ground zero the radial miss distance, R, is computed as N(0,CEP/1.1774) while an angle, A, is picked from U(0,2π). Ground zero is then placed at the polar coordinates of (R,A)

The actual yield is selected from a normal distribution with nominal yield as the mean. (Actual variances are classified) The standard deviation is assumed to be one tenth of the mean.

HOB is selected from a normal distribution with DHOB as the mean and PEH/.67 as the standard deviation.

The actual GZ, yield and HOB have now been fixed and the burst parameters are output by the statement;

```
LIST X, Y, YIELD, HOB
```

EACH TANK in TANK.SET(TARGET) and TROOP in TROOP.SET(TARGET) is examined to check for damage. As stated, the TANK can only be fully operatinal (TANK.DEAD = 0) or killed (TANK.DEAD = 3). The only mechanism which has any reasonable chance to destroy a tank is overpressure. The overpressure at which a TANK has a 50% chance of survival is 25 psi. Thus;

```
LET RD.OVER.PRESSURE = OVER.PRESSURE(YIELD,25)
```

will return the distance from GZ where 25 psi will be encountered and will be used to determine if the TANK is destroyed.

```
IF (R/RD.OVER.PRESSURE LE .5) OR
(.01*(NEUTRON(R,YIELD) PLUS GAMMA(R,YIELD)) GT 18000)
```

is a compound IF statement which destroys the TANK (TANK.DEAD = 3) if either of the following conditions are met.

1. If the probability of destruction by overpressure is greater than 99.5% or
2. If the crew inside would receive more than 18,000 rads of radiation.

The TROOP is put through all four damage mechanisms before being declared a survivor. The thermal level at which a TROOP has a 50% chance of survival is 20 cal/cm . Thus;

```
LET RD.HEAT = HEAT(yield,20)
```

will return the distance from GZ where 20 cal/cm will be encountered and will be used to determine if the TROOP is killed. To become a thermal casualty a compound IF statement must be true:

The TROOP must be exposed (TRANS.FACTOR(TROOP) = 1) and
The TROOP must receive enough thermal energy to become a thermal casualty (PROBABILITY(R/RD.HEAT) LT CHANCE) and
His reaction time must be greater than .1 second.

If the TROOP survives the first test, he may become a casualty due to overpressure. The overpressure at which a TROOP has a 50% chance of survival is 10 psi. Thus;

```
LET RD.OVER.PRESSURE = OVER.PRESSURE(YIELD,10)
```

will return the distance from GZ where 10 psi will be encountered
and will be used to determine if the TROOP is destroyed.

If R/RD is less than .5, the TROOP is killed (TROOP.DEAD = 3). Otherwise he must take a Monte Carlo chance;

```
IF PROBABILITY (R/RD.OVER.PRESSURE) LT CHANCE
```

If the above statement is true then the TROOP is killed.

If the TROOP is still alive, he must now survive the effects of dynamic pressure. This section is identical to overpressure with the exception of a call to DYNAMIC.PRESSURE instead of OVER.PRESSURE to get RD.DYNAMIC.PRESSURE

After all of this, if the TROOP is still alive, nuclear radiation gets its chance. The combined effects of neutron and gamma gamma radiation are added to the current radiation level.

```
ADD TRANS.FACTOR(TROOP)*((NEUTRON(R,YIELD)+GAMMA(R,YIELD)))
TO ACCUM.DOSE(TROOP)
```

If the TROOP has accumulated more than 18,000 rads he is killed (TROOP.DEAD = 3).

If the ACCUM.DOSE is between 8,000 and 18,000 rads he is placed in the incapacitated state(TROOP.DEAD(TROOP) = 2) until he is killed in 2 to 5 days.

```
LET T.LETH(TROOP) =RANDI.F(2*24*60,5*24*60,1)
```

If the ACCUM.DOSE is between 3,000 and 8,000 rads he is placed in the incapacitated state for 30 to 45 minutes.

```
LET T.IMPAIR.NUC(TROOP) = RANDI.F(30,45,1)
```

At the end of this time he is placed in the functionally impaired state (TROOP.DEAD(TROOP) = 1). He is killed in 2 to 5 days.

If the ACCUM.DOSE is between 2,000 and 3,000 rads he is placed in the functionally impaired state until he is killed in 2 to 5 days.

If the ACCUM.DOSE is greater than what he can tolerate (LETHAL.DOSE(TROOP)) but less than 2,000 rads the TROOP is unaffected for a short period of time - 30 to 60 minutes.

```
LET T.IMPAIR.NUC(TROOP) = RANDI.F(30,60,1)
```

At the end of this time he is placed in the functionally impaired state. He is killed in 2 to 5 days.

If ACCUM.DOSE is less than LETHAL.DOSE(TROOP) then he is fully functional and will not be killed as a result of the current detonation.

K. FUNCTION OVER.PRESSURE

This function determines the distance from GZ at which a target element will encounter a 50% chance of survival for the achieved yield and required operpressure.

L. FUNCTION DYNAMIC.PRESSURE

This function determines the distance from GZ at which a target element will encounter a 50% chance of survival for the achieved yield and required dynamic pressure.

M. FUNCTION ARRIVAL.TIME

This function executes the arrival time function and returns the time after detonation when the blast wave will pass the given distance fromn GZ.

N. FUNCTION GAMMA

Equation 2.4 is executed by this function. For the achieved yield and distance from GZ the amount of neutron radiation is returned.

O. FUNCTION NEUTRON

Equation 2.3 is executed by this function. For the achieved yield and distance from GZ the amount of neutron radiation is returned.

P. FUNCTION HEAT

Equation 2.2 is executed by this function. For the achieved yield and thermal requirement the distance from GZ where a 50% chance of lethal burns occurs is returned.

Q. FUNCTION PROBABILITY

This function approximates the area under a N(0,1) probability curve. It is a table look-up for Fig. 4.8. Only entry arguments (R/RD) of .5 and greater are passed to it. If the argument is greater than 1.5 the probabilitiy is set to 0.

VI. ENHANCEMENTS AND EXTENSIONS

A. OPTIMUM ASSIGNMENT OF BATTERIES.

This model assigns batteries to fire on an essentially random basis. There is no thought given to optimizing the coverage. Choosing the highest coverage for each target on a first in first out basis may not provide maximum total coverage. An assignment problem must be solved to do this correctly.

Table IV is a potential nuclear load for three batteries in the following example.

TABLE IV

Nuclear Load by Battery

		No. of rounds			
Battery	Type	.2 KT	1 KT	2 KT	8 KT
1	SRC	1	2	0	0
2	SRC	1	1	0	0
3	MRC	0	0	1	2

Table V shows the coverages that can be obtained with the various battery/yield combinations on five targets. A zero means that the target is either out of range or coverage is less than command guidance. Note that battery 1 has 2 rounds of 1 KT yield and, thus, has 2 identical rows for the 1 KT rounds. A similar situation is true for the 8 KT rounds of battery 3.

TABLE V

Target Coverage

Battery	Yield	Target 1	2	3	4	5
	.2 KT	.72	.00	.00	.00	.00
1	1 KT	.82	.80	.00	.45	.00
	1 KT	.82	.80	.00	.45	.00
	.2 KT	.75	.00	.42	.00	.00
2	1 KT	.85	.00	.51	.42	.00
	2 KT	.92	.63	.47	.97	.92
3	8 KT	.97	.00	.00	.00	.00
	8 KT	.97	.00	.00	.00	.00

To assign battery/yield combinations to a target according to the current technique would produce the following;

Target	Battery/Yield	Coverage
1	3/8 Kt	.97
2	1/1 Kt	.80
3	2/1 Kt	.51
4	3/2 Kt	.97

This arangement results in a total coverage of 3.25, but target number 5 cannot be engaged because the only feasible round for it was employed on target number 4. The assignment problem that needs to be solved is one that will maximize total coverage. This case is very easy to solve by inspection.

The optimum assignment is;

Target	Battery/Yield	Coverage
1	3/8 Kt	.97
2	1/1 Kt	.80
3	2/1 Kt	.51
4	1/1 Kt	.45
5	3/2 Kt	.92

The optimum total coverage is then 3.65.

In the current model, only the percentage of coverage is used to elvaluate the value of the target. This may not be the item to maximize if the various targets are not of the same type and population. For example, a 97% coverage on an infantry company is not as valuable as a 50% coverage on a tank regiment. To make the matrix in Table V more realistic, a variable such as;

Value = coverage * element value * target population

should be used.

B. VARIATION OF MSD

Typically, an operations order specifies the troop safety guidance as a negligible risk to unwarned exposed personnel. This is the category used in the model to determine MSD. Fig. 6.1 shows the different separation distances that must be achieved for the safety categories of;

1. Unwarned exposed.
2. Warned exposed.
3. Warned protected.

Each category has the 3 levels of radiation exposure status(RES) of;

1. Negligible.
2. Moderate.
3. Emergency.

	UNWARNED EXPOSED			WARNED EXPOSED			WARNED PROTECTED		
RANGE	NEG	MOD	EMER	NEG	MOD	EMER	NEG	MOD	EMER
2000	7500	6900	4500	4400	4100	3200	3400	3000	1600
3000	7500	6900	4500	4400	4100	3300	3500	3100	1600
4000	7500	7000	4500	4400	4100	3300	3500	3100	1700
5000	7600	7000	4600	4500	4200	3300	3600	3200	1700
6000	7600	7000	4600	4500	4200	3300	3600	3200	1700
7000	7600	7000	4600	4500	4200	3400	3700	3300	1800
8000	7600	7100	4600	4500	4200	3400	3700	3300	1800
9000	7700	7100	4700	4600	4300	3400	3800	3400	1800
10000	7700	7100	4700	4600	4300	3400	3900	3500	1800
11000	7700	7100	4700	4600	4300	3500	4000	3500	1900
12000	7700	7200	4700	4600	4300	3500	4000	3600	1900
13000	7600	7200	4800	4700	4400	3500	4100	3700	1900
14000	7800	7200	4800	4700	4400	3500	4200	3700	1900
15000	7800	7200	4800	4700	4400	3600	4300	3800	2000
16000	7800	7300	4800	4700	4400	3600	4300	3900	2000
17000	7900	7300	4900	4800	4500	3600	4400	3900	2000
18000	7900	7300	4900	4800	4500	3600	4500	4000	2000

Figure 6.1 Minimum Separation Distances.

In Fig. 6.1 the MSD for a negligible risk to unwarned exposed and warned exposed personnel are 7700 and 4600 meters respectively. Recall that MSD is the reason for offset and offset is the reason for some very severe degradation in coverage. If the 4600 meter MSD could be used, then the displacement could be reduced by 4300 meters. This could make a significant difference in the final outcome of the simulation.

Expansion of the MSD category would greatly expand the use of the model as an analytical tool.

C. COLLATERAL DAMAGE AVOIDANCE.

Chapter 14 of Ref. 2 contains least separation distances (LSD) to avoid damage to many entities such as buildings, forests, bridges and civilian populations. This imposes the same type of offset requirement on the aimpoint as MSD does except that it precludes damage to entities other than friendly troops.

Use of this idea would require implementation of a routine similar to that which determines offset except that the description of what is being avoided must also be included.

D. MULTIPLE TARGETS

As it has already been shown, the center of a target need not be the aimpoint. It would be highly advantageous to destroy more than one target with a single burst. Fig. 6.2 shows 3 targets and their associated maximum

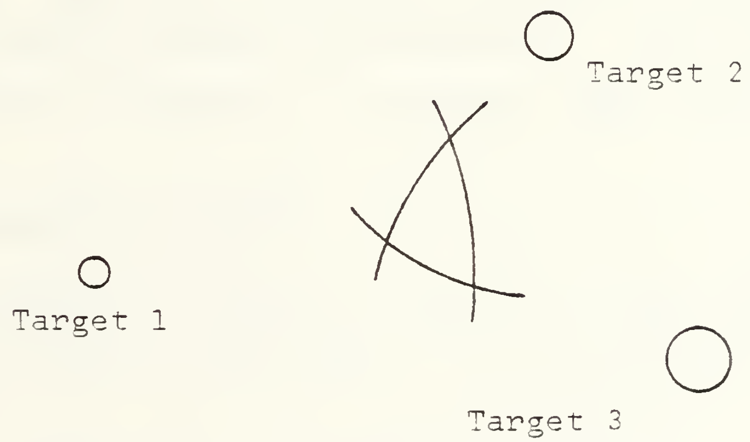

Figure 6.2 Multiple Targets.

displacement distance to insure minimum acceptable coverage. The "triangular" area that is inside all circles is a feasible area for each target. That is, a round employed anywhere in the "triangle" will destroy all 3 targets.

A method to evaluate groups of targets would greatly expand the use of the model as an analytical tool.

E. FALLOUT

Generally, nuclear weapons are detonated at or above an altitude that provides a 99% assurance of no fallout (Eqs. 3.4 and 3.5). However, fallout may be an effective barrier to movement or cause mass evacuation of a contaminated area. Control of fallout after employment is impossible due to atmospheric conditions and the user may become the victim.

Should a ground burst occur, it is necessary to predict and simulate fallout. Predicting fallout requires that meterological data at altitudes up to and including cloud top must be known. A deterministic model for predicting fallout is relatively simple but actually simulating fallout may require assistance from experts in meteorology.

F. ACTIONS TAKEN DURING AND AFTER FALLOUT.

While the detonation of nuclear weapons will certainly cause some unique actions and reactions, there are some specific actions required of soldiers upon encountering fallout.

1. Optimum Time of Exit.

For personnel caught in a fallout area (presumably in covered fox holes or shelters) there is an optimum time to exit the area to minimize the absorption of nuclear radiation.

While soldiers stay in the protective confines of their fox holes, they take advantage of the shielding. They also prolong their exposure time. To immediately leave would reduce their exposure time but would expose them to a much higher dose rate outside their shelters.

For given initial dose rate, decay rate, shielding and exposure time to a safe area, there is an optimum time to leave.

2. Crossing Problem.

Given that a unit must cross a radiation area, there is a not-earlier-than time before which they may not enter. It is a function of RES, fallout pattern and decay rate, speed of crossing and shielding during the crossing. Inclusion of this type of problem into the the maneuver section of a driver routine would certainly have an impact upon the outcome of the simulation.

3. Decontamination.

Actions taken to decontaminate vehicles and personnel are relatively simple if only transportation to and from a decontamination site and time taken to decontaminate are considered. The main problem with decontamination is one of supply.

G. ADDITIONAL TARGET ELEMENTS.

The current model has only tanks and troops in the target areas. Any target may be added to the target array by defining it as a temporary entity and allowing a target to own it. To damage the entity requires the modeler to call one or more of the damage functions with the appropriate arguments and then decide if the entity is damaged. The procedure is virtually identical to what is currently used.

APPENDIX A
REGRESSION ANALYSIS

A. GAMMA RADIATION

Since the model needs the gamma radiation level at a specific range for a given yield, it is advantagous to replot Fig. 2.7 with dose as the dependent variable. Fig. A.1 is this new plot.

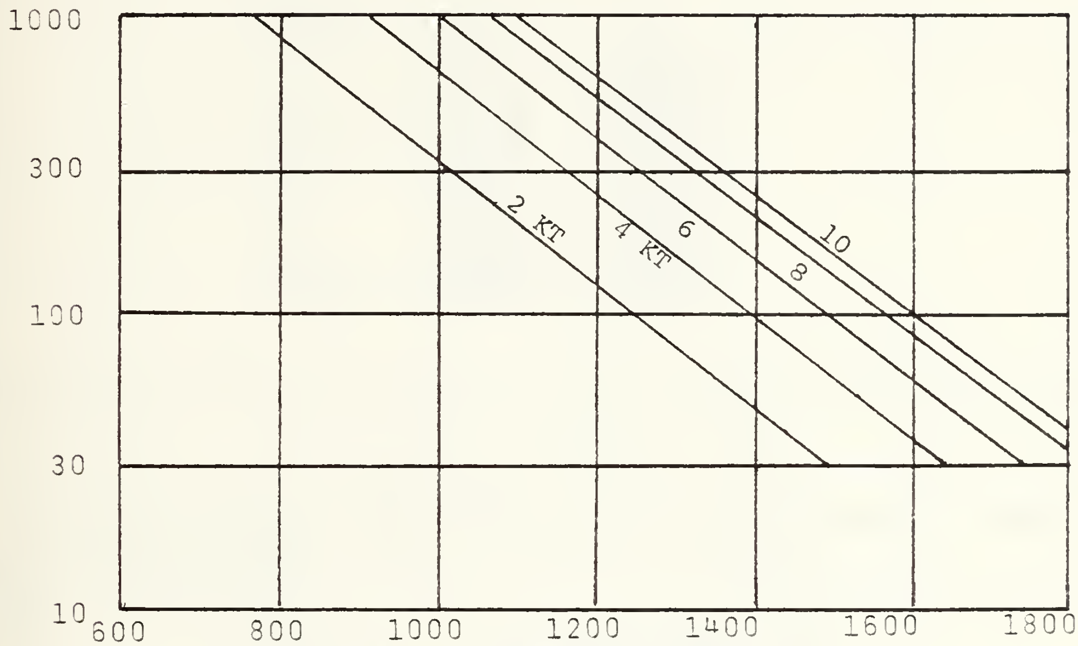

Figure A.1 Gamma Radiation.

Surrendering this plot to the APL linear regression package for the equation;

$$\ln(\text{Dose}) = A + B * \text{Range} + C * \ln(\text{Yield})$$

fails to provide an adequate solution. Therefore, the model was solved in pieces and reassembled.

The procedure was to regress each line independently as

$$\ln(\text{Dose}) = A + B * \text{Range}$$

for each yield. The coefficients A and B are obtained for each yield and are listed in Table VI.

TABLE VI
Coefficients A and B.

Yield	A	B
1	11.18	-.0060
2	11.56	-.0056
3	11.76	-.0054
4	11.91	-.0052
5	12.02	-.0052
6	12.22	-.0051
7	12.22	-.0050
8	12.33	-.0050
9	12.38	-.0049
10	12.42	-.0049

For each yield, the coefficients are plotted as shown in Figs. A.2 and A.3.

Figure A.2 Regression Coefficient A (Data).

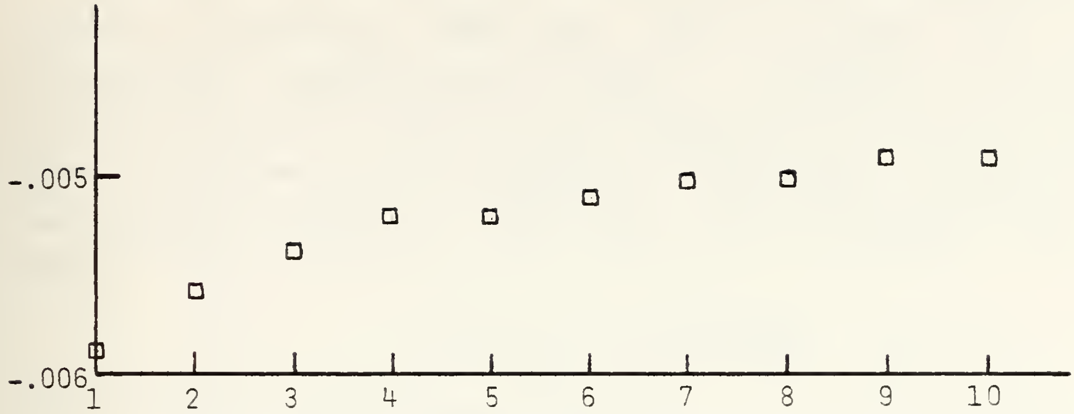

Figure A.3 Regression Coefficient B (Data).

The coefficients can now be regressed against yield. From Fig. A.2 the first coefficient appears to vary as the square root of yield. Therefore, the equation;

$$A = C_0 + C_1 \cdot \sqrt{\text{Yield}}$$

is fit with the following results.

$$C_0 = 10.74$$

$$C_1 = .5599$$

This equation is plotted in Fig. A.4 along with the original coefficient data. The fit is quite good.

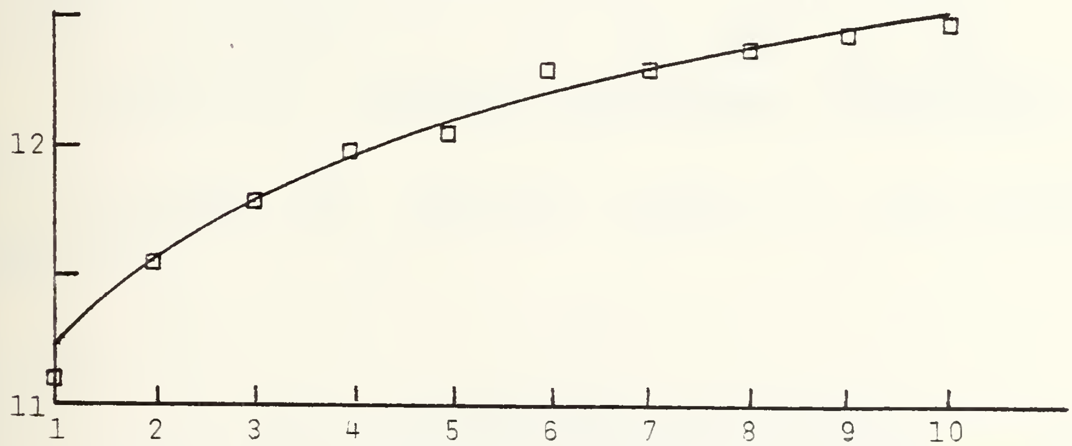

Figure A.4 Regression Coefficient A (Regressed).

There is a temptation to say that the coefficient, B, is really a constant since the curve is very flat and the represented values are so small. However, it must be remembered that this is to be multiplied by the range and the result used as an exponent. Any small error may have catastrophic results. From Fig. A.3 a straight line of the form;

$$B = C_0 + C_1 * \text{Yield}$$

is fit with the following results.

$$C_0 = -.0058$$

$$C_1 = .0001$$

The equation is plotted in Fig. A.5 along with the original coefficient data.

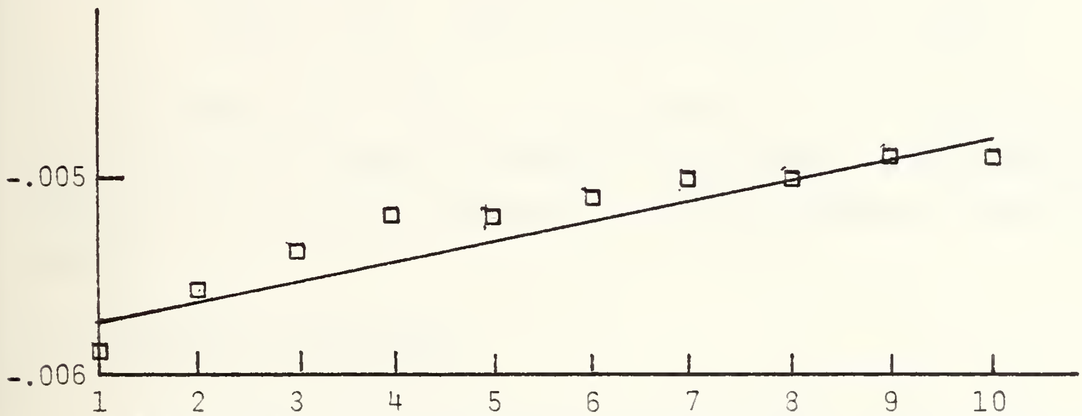

Figure A.5 Regression Coefficient B (Regressed).

Assembling the equation results in the following equation.

$$G = 46166 \cdot \frac{e^{.5599\sqrt{\text{Yield}}}\, e^{.0001 \cdot \text{Yield} \cdot R}}{e^{.0058 \cdot R}} \qquad \text{(A.1)}$$

Equation A.1 is plotted on Fig. A.6 for even yields along with the original data.

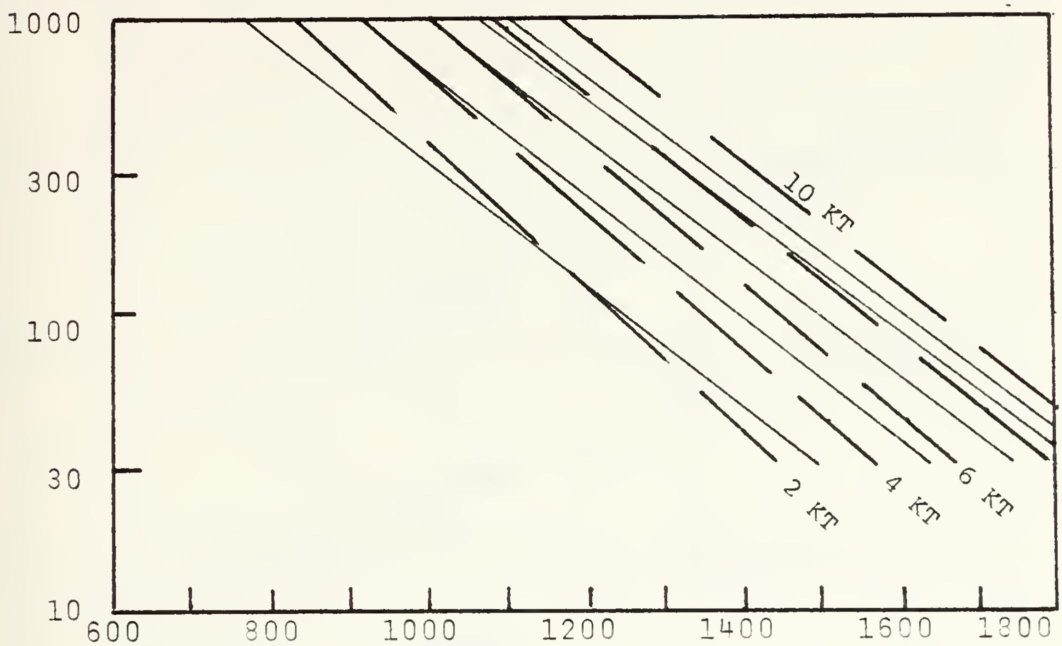

Figure A.6 Full Gamma Regression Model.

It is important that the equation be accurate in the vicinity of 650 rads as this is the mean of the lethal dose distribution and is the dividing point between surviving and dying.

B. NEUTRON RADIATION

Like gamma radiation, the model needs the neutron radiation level at a specific range for a given yield. However, Fig. 2.6 appears to have straight lines which can be exploited in a regression analysis. Fig. 2.6 has been converted to a metric scale and is presented in Fig. A.7.

The neutron regression model was also split into two submodels. Each line was regressed independently as;

$$\text{Range} = A + B * \ln(\text{Yield})$$

for each dose.

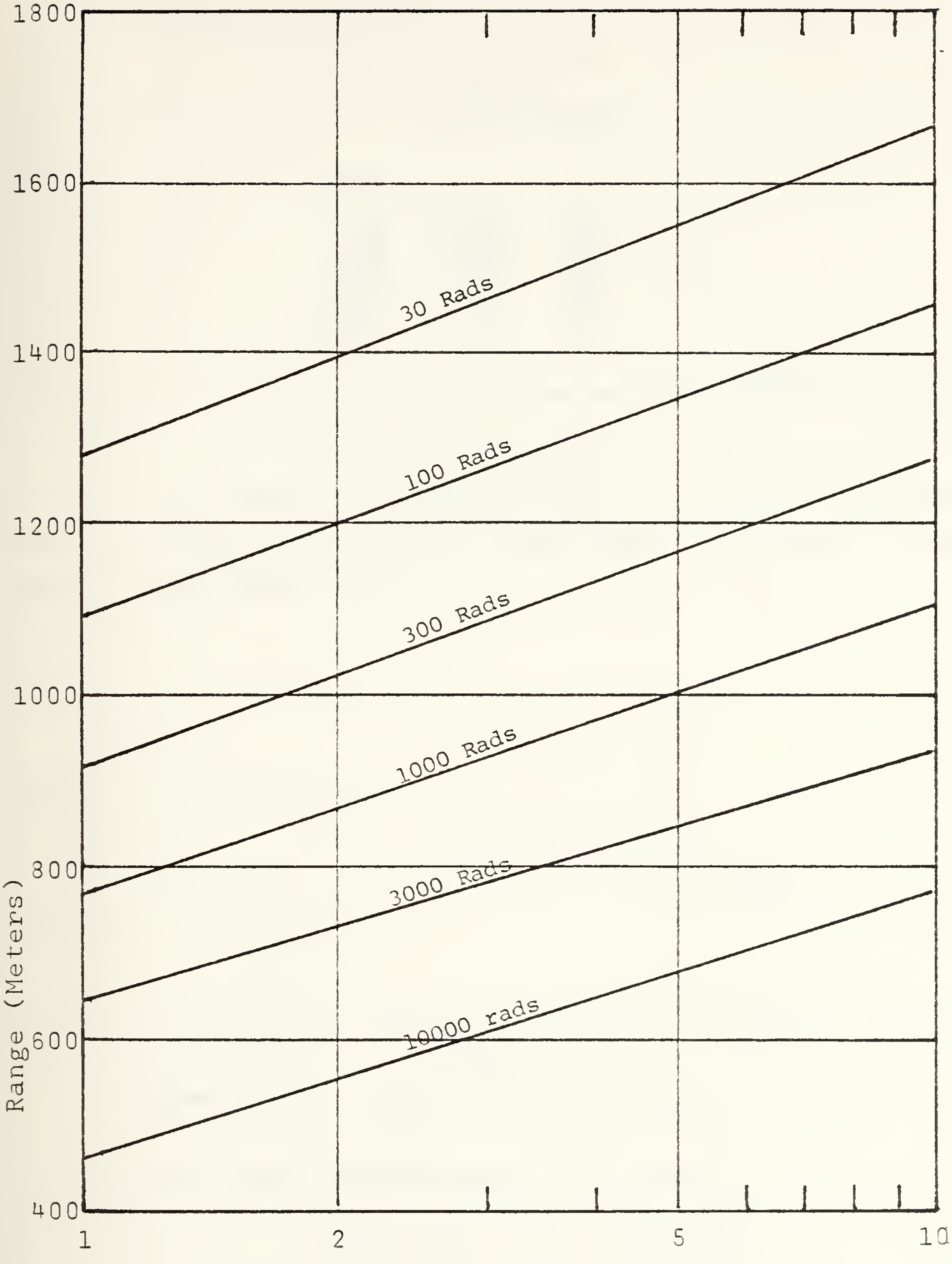

Figure A.7 Neutron Radiation.

The coefficients A and B are obtained for each dose and are listed in Table VII.

TABLE VII

Coefficients

Dose	A	B
30	1272	171
100	1093	158
300	918	156
1000	766	148
3000	641	129
10000	461	138

For each dose, the coefficients are plotted as shown in Figs. A.8 and A.9. The coefficients can now be regressed against the dose.

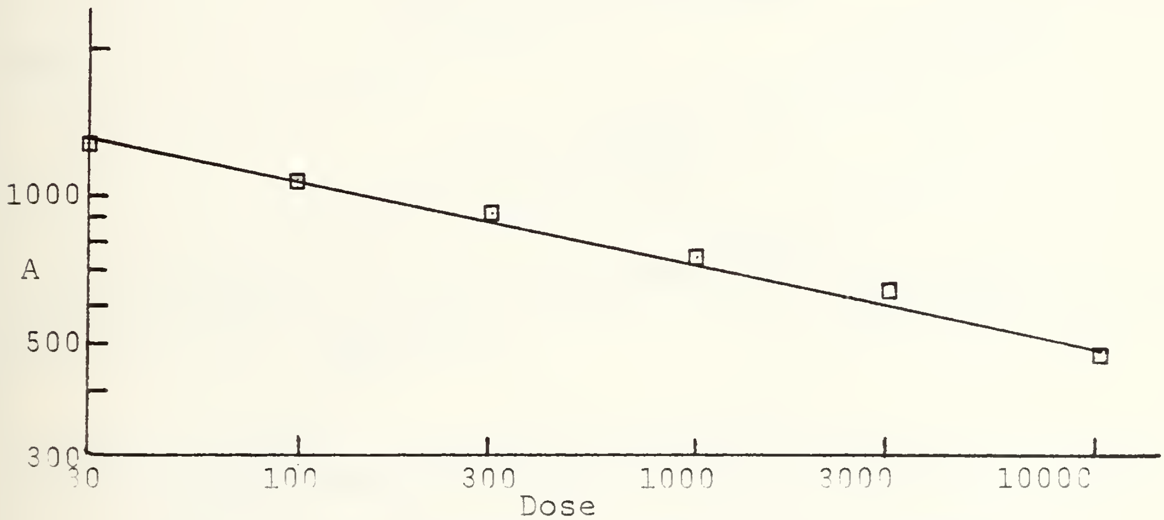

Figure A.8 Regression Coefficient A (Data).

For the first coefficient, A, the model is

$$\ln(A) = C_0 + C_1 * \ln(\text{Dose})$$

with

$$C_0 = 7.77$$

$$C_1 = -.1696$$

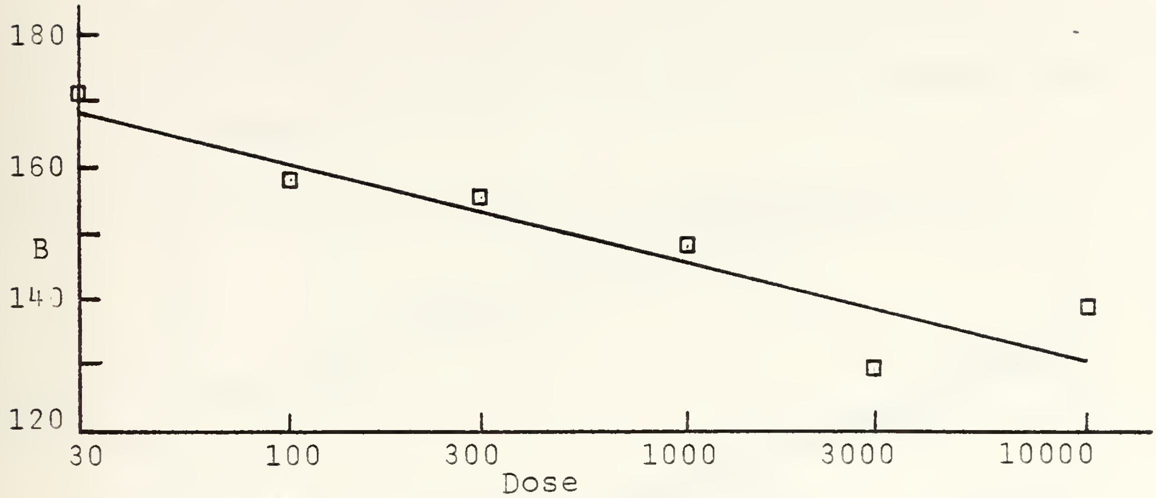

Figure A.9 Regression Coefficient B (Data).

For the second coefficient, B, the model is

$$B = C_0 + C_1 * \ln(\text{Dose})$$

with

$$C_0 = 190.45$$

$$C_1 = -6.4145$$

The submodels can now be assembled and result in the following full model.

$$\text{Range} = \frac{2368.47}{\text{Dose}^{.1696}} + (190-6.4 \cdot \ell n(\text{Dose})) \cdot \ell n(\text{Yield}) \qquad \text{(A.2)}$$

What the model needs is a function of range and yield which yields dose. Equation A.2 cannot be separated to do this, therefore an approximation is offered. The term;

$$190 - 6.4 * \ln(\text{Dose})$$

is the slope of the line for a given dose. For doses from 30 to 10,000 rads, the average slope is 150. The proposal

is to use 150 as the slope for every line. Fig. A.3 has the data plotted again as well as Eq. A.2 and the new proposal. For doses of 3,000 rads and below the new proposal seems to be an improvement.

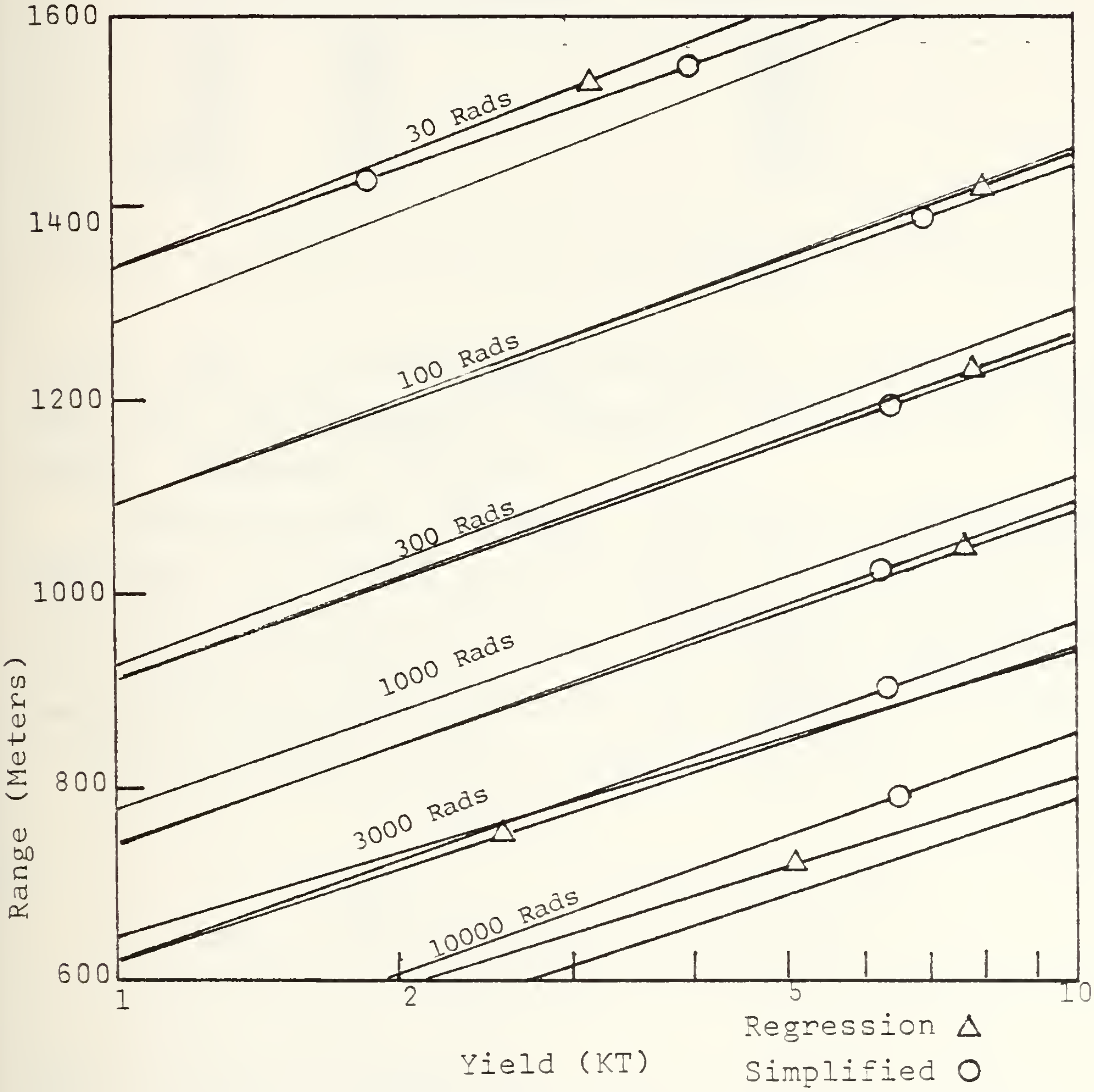

Figure A.10 Neutron Radiation and Regression.

Table VIII lists the full model slope and the percent error if a slope of 150 is used. Notice that the error is negative at low doses but is getting larger. Thus, it is expected to be in perfect agreement at some dose. That dose

TABLE VIII

Slope Approximation

Dose	190 - 6.4·ln(Dose)	Change from 150
30	168	-12%
100	160	-06%
300	153	-02%
518	150	00%
1000	146	03%
3000	138	08%
10000	131	13%

is 518 rads. As with gamma radiation, it is important that the model be accurate at radiation levels of 650 rads and below. Obviously, this is.

Above 518 rads, the error is positive and continues to increase. At 10,000 rads the error is about the same as at 30 rads. This seems to be a warning about extrapolation. It would be unwise to use this formula for ranges and radiation levels outside those from which it was derived.

Using the approximation, Eq. A.2 becomes

$$\text{Range} = \frac{2368.47}{\text{Dose}^{.1696}} + 150\cdot \ell n(\text{Yield})$$

which can now be separated.
The rearranged formula is;

$$\text{Dose} = \left(\frac{2368.47}{R-150\cdot \ell n(\text{Yield})}\right)^{5.896} \qquad \text{(A.3)}$$

C. THERMAL RADIATION

The model uses a thermal radiation equation which yields range as a function of yield and radiant exposure. Fig. 2.2 is already in that format with the exception that range is in miles. Fig. A.11 is the same figure using a metric range scale.

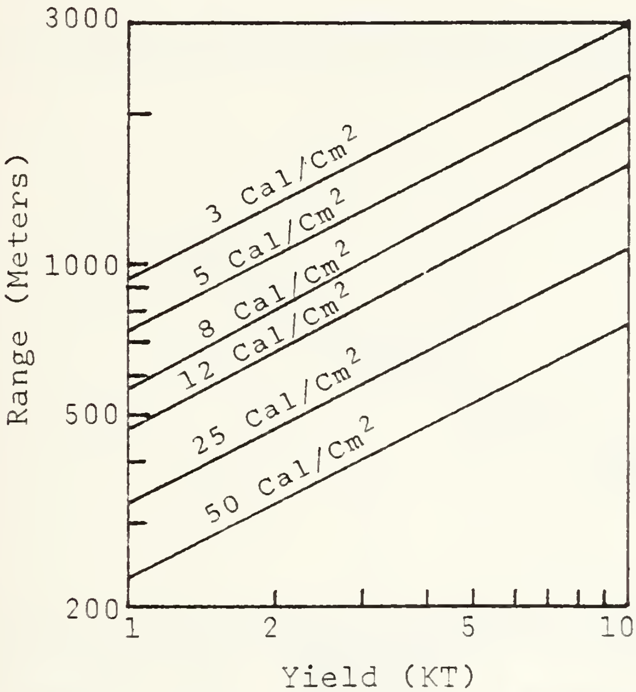

Figure A.11 Thermal Radiation.

The previously used method of using submodels will again be used. The full model is;

$$Range = A + B * \ln(Yield)$$

for each exposure. The coefficients A and B are obtained for each exposure and are listed in table IX .

For each exposure, the coefficients are plotted as shown in Figs. A.12 and A.13. The coefficients can now be regressed against the exposure.

TABLE IX

Regression Coefficients A and B

Exposure	A	B
3	6.8331	.5136
5	6.5728	.5051
8	6.3238	.5239
12	6.1137	.5180
25	5.7786	.4926
50	5.4593	.4773

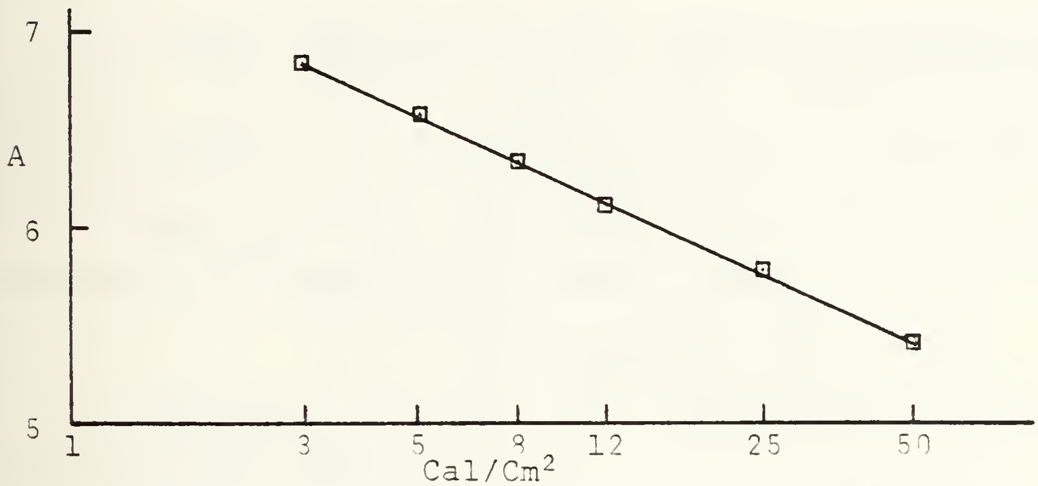

Figure A.12 Regression Coefficient A (Data).

For the first coefficient, A, the model is

$$A = C_0 + C_1 * \ln(\text{exposure})$$

with

$$C_0 = 7.3528$$

$$C_1 = -.4885$$

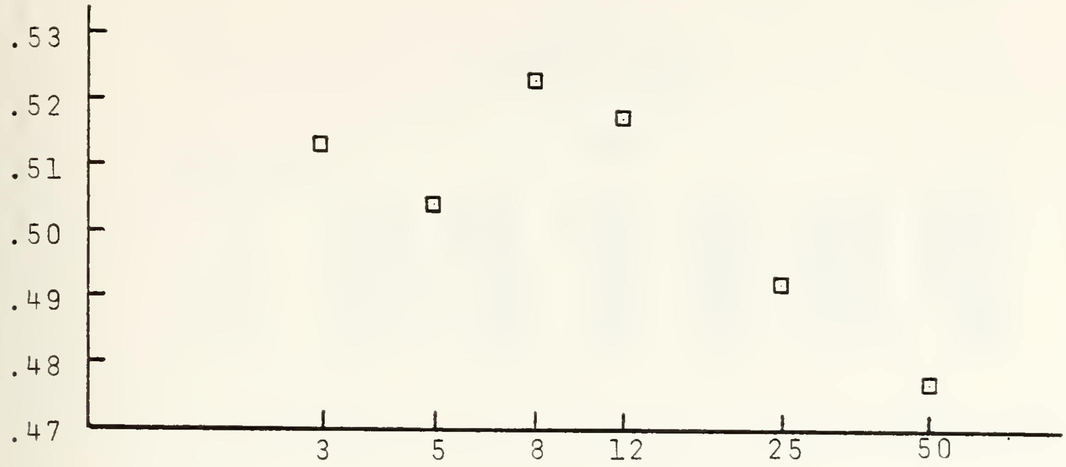

Figure A.13 Regression Coefficient B (Data).

The second coefficient could now be regressed against exposure, but several models tried failed to yield an accurate explanation of behavior of the coefficient as a function of exposure. This makes sense since B is the slope of a given line and all lines appear to be parallel. Therefore, an average slope value is used.

$$B = .5051$$

The submodels can now be assembled and result in the following full model.

$$\text{Range} = 1561 \cdot \frac{(\text{Yield})^{.5051}}{(\text{Exposure})^{.4885}} \tag{A.4}$$

Normally, a figure would be used to compare the data to the regression lines at this point. However, the agreement is so good that a graph would lack enough detail to reveal any differences. Therefore, Tables X and XI will be offered to show how well the curve fit is.

TABLE X

Original Data

Exposure	Yield 1	2	3	5	7	10
3	933	1289	1609	2253	2594	2896
5	708	1014	1271	1609	1931	2253
8	563	805	982	1287	1496	1931
12	450	644	805	1046	1255	1464
25	322	451	563	724	837	998
50	241	322	386	499	612	708

TABLE XI

Regression Results

Exposure	Yield 1	2	3	5	7	10
3	912	1295	1590	2058	2439	2920
5	711	1009	1239	1603	1900	2275
8	565	802	985	1274	1510	1809
12	464	658	808	1045	1239	1484
25	324	460	564	730	866	1037
50	230	328	402	521	617	739

As one can clearly see, the fit is excellent, but the same caution about extrapolation must apply. Equation A.4 is valid only within the range of the data.

APPENDIX B

MODEL LISTING FILE

This appendix contains a copy of the listing file for a test run of the model. There are three targets, five batteries and three companies. Each target has 50 tanks and 50 troops uniformly distributed within the RT. Table XII lists the target data while Table XIII lists the battery data and Table XIV lists the company data. Target types are as listed on page 68.

TABLE XII

Target Data

Target	Type	X Coordinate	Y Coordinate	RT
1	1	9500.0	0.0	1400.0
2	4	8000.0	0.0	400.0
3	5	6000.0	0.0	300.0

TABLE XIII

Battery Data

Battery	Size	X Coordinate	Y Coordinate
1	SRC	0.0	0.0
2	MRC	1000.0	0.0
3	SRC	1000.0	500.0
4	MRC	500.0	0.0
5	SRC	1500.0	250.0

TABLE XIV

Company Data

Company	X Coordinate	Y Coordinate	Radius
1	2000.0	500.0	200.0
2	2000.0	0.0	200.0
3	2000.0	-500.0	200.0

```
PREAMBLE
PERMANENT ENTITIES
  GENERATE LIST ROUTINES
  EVERY BATTERY HAS A SIZE, AN XB, A YB AND SOME NUC.ROUNDS
  EVERY COMPANY HAS A XC, A YC, A ZC AND A CO.RADIUS
  EVERY TARGET HAS A TYPE, A XT, A YT, A ZT, A RT
        AND MAY OWN A TANK.SET, A TROOP.SET, AND A LISTING
TEMPORARY ENTITIES
  EVERY TANK HAS A X.TANK, A Y.TANK, A TANK.DEAD,
        AND MAY BELONG TO A TANK.SET
  EVERY TROOP HAS A X.TROOP, A Y.TROOP, A TRANS.FACTOR, A TROOP.DEAD,
        A LETHAL.DOSE, AN ACCUM.DOSE, A T.LETH, A T.IMPAIR.NUC
        AND MAY BELONG TO A TROOP.SET
  EVERY SOLUTION HAS A UNIT.TO.FIRE, AN XDGZ, A YDGZ, AN IYIELD,
        A JROW, A KCOL AND A PCT AND BELONGS TO A LISTING
DEFINE SIZE, TYPE, UNIT.TO.FIRE, NUC.ROUNDS, TANK.DEAD,
       TROOP.DEAD, T.LETH, T.IMPAIR.NUC, IYIELD, JROW,
       KCOL AS INTEGER VARIABLES
DEFINE X.TANK, Y.TANK, X.TROOP, Y.TROOP,
       LETHAL.DOSE, ACCUM.DOSE, XB, YB, XC, YC, ZC, CO.RADIUS,
       XT, YT, ZT, RT, POXPCT, PCT, XDGZ, YDGZ, TRANS.FACTOR
       AS REAL VARIABLES
DEFINE LISTING AS A SET RANKED BY HIGH PCT AND THEN BY LOW IYIELD
DEFINE NCOLS, SRC.NROWS, MRC.NROWS, SRC.NYIELDS, MRC.NYIELDS, NTABLES AS
       INTEGER VARIABLES
DEFINE SRC.P.COVERAGE AS A REAL, 4-DIMENSIONAL ARRAY
DEFINE MRC.P.COVERAGE AS A REAL, 4-DIMENSIONAL ARRAY
DEFINE SRC.RANGES AS A REAL, 1-DIMENSIONAL ARRAY
DEFINE MRC.RANGES AS A REAL, 1-DIMENSIONAL ARRAY
DEFINE SRC.TABLE.RT AS A REAL, 3-DIMENSIONAL ARRAY
DEFINE MRC.TABLE.RT AS A REAL, 3-DIMENSIONAL ARRAY
DEFINE SRC.YIELDS AS A REAL, 1-DIMENSIONAL ARRAY
DEFINE MRC.YIELDS AS A REAL, 1-DIMENSIONAL ARRAY
DEFINE MSD.SRC AS A 2-DIMENSIONAL REAL VARIABLE
DEFINE MSD.MRC AS A 2-DIMENSIONAL REAL VARIABLE
DEFINE CD90.SRC AS A 1-DIMENSIONAL REAL VARIABLE
DEFINE CEP.SRC  AS A 1-DIMENSIONAL REAL VARIABLE
DEFINE HOB.SRC  AS A 3-DIMENSIONAL REAL VARIABLE
DEFINE PEH.SRC  AS A 1-DIMENSIONAL REAL VARIABLE
DEFINE CD90.MRC AS A 1-DIMENSIONAL REAL VARIABLE
DEFINE CEP.MRC  AS A 1-DIMENSIONAL REAL VARIABLE
DEFINE HOB.MRC  AS A 3-DIMENSIONAL REAL VARIABLE
DEFINE PEH.MRC  AS A 1-DIMENSIONAL REAL VARIABLE
DEFINE SRC.MIN.RD AS A 3-DIMENSIONAL REAL VARIABLE
DEFINE SRC.EXP.RD AS A 3-DIMENSIONAL REAL VARIABLE
DEFINE MRC.MIN.RD AS A 3-DIMENSIONAL REAL VARIABLE
DEFINE MRC.EXP.RD AS A 3-DIMENSIONAL REAL VARIABLE
DEFINE CD90.RT AS A 1-DIMENSIONAL REAL VARIABLE
DEFINE RD.RT AS A 1-DIMENSIONAL REAL VARIABLE
DEFINE D.CD90 AS A 1-DIMENSIONAL REAL VARIABLE
DEFINE DISPLACED.COVERAGE AS A 2-DIMENSIONAL REAL VARIABLE
DEFINE A.OVER AS A 2-DIMENSIONAL REAL VARIABLE
DEFINE A.DYNAMIC AS A 2-DIMENSIONAL REAL VARIABLE
DEFINE GZ.RD AS A 2-DIMENSIONAL REAL VARIABLE
DEFINE EXP.COVERAGE AS A REAL FUNCTION
DEFINE OFFSET.COVERAGE AS A REAL FUNCTION
DEFINE INTERP AS A REAL FUNCTION
DEFINE HEAT AS A REAL FUNCTION
DEFINE GAMMA AS A REAL FUNCTION
DEFINE NEUTRON AS A REAL FUNCTION
DEFINE OVER.PRESSURE AS A REAL FUNCTION
DEFINE DYNAMIC.PRESSURE AS A REAL FUNCTION
DEFINE ARRIVAL.TIME AS A REAL FUNCTION
DEFINE PROBABILITY AS A REAL FUNCTION
END ''OF PREAMBLE
```

```
MAIN
LET LINES.V = 75
DEFINE POLICY AS A REAL, 1-DIMENSIONAL ARRAY
DEFINE RANGE AS A REAL VARIABLE
DEFINE I AS AN INTEGER VARIABLE
READ NTABLES
RESERVE POLICY(*) AS NTABLES
CALL READ.RESERVE
READ POLICY
READ N.BATTERY
      CREATE EVERY BATTERY
      FOR EVERY BATTERY, READ SIZE(BATTERY), XB(BATTERY),YB(BATTERY)
       ,NUC.ROUNDS(BATTERY)
PRINT 1 LINE THUS
BATTERY  SIZE      X         Y        ROUNDS
POR EVERY BATTERY, PRINT 1 LINE WITH BATTERY,SIZE(BATTERY),XB(BATTERY),
YB(BATTERY),NUC.ROUNDS(BATTERY) THUS
  **     **     *****.*   *****.*       **
READ N.COMPANY
      CREATE EVERY COMPANY
      FOR EVERY COMPANY, READ XC(COMPANY), YC(COMPANY),ZC(COMPANY)
       ,CO.RADIUS(COMPANY)
PRINT 1 LINE THUS
COMPANY     X         Y        Z         RADIUS
POR EVERY COMPANY, PRINT 1 LINE WITH COMPANY,XC(COMPANY),YC(COMPANY),
ZC(COMPANY),CO.RADIUS(COMPANY) THUS
  **     *****.**    *****.*  *****.*        **
READ N.TARGET
      CREATE EVERY TARGET
      FOR EVERY TARGET, READ TYPE(TARGET), XT(TARGET), YT(TARGET),
      ZT(TARGET) AND RT(TARGET)
      NOW INITIALIZE
    FOR EVERY TARGET, DO
      FOR EVERY BATTERY, DO
         LET RANGE=SQRT.F(((XT(TARGET)-XB(BATTERY))**2)+
                          ((YT(TARGET)-YB(BATTERY))**2))
         PERFORM ANALYSIS GIVEN TYPE(TARGET), SIZE(BATTERY), RT(TARGET)
          ,RANGE, TARGET, BATTERY, POLICY(TYPE(TARGET))
      LOOP
    LOOP
    FOR EVERY TARGET, DO
      LIST ATTRIBUTES OF TARGET
      LIST ATTRIBUTES OF EVERY SOLUTION IN LISTING(TARGET)
    LOOP
```

```
    FOR EVERY TARGET,DC
       START NEW PAGE
       REMOVE THE FIRST SOLUTION FROM LISTING(TARGET)
       LIST ATTRIBUTES OF SOLUTION
       IF NUC.ROUNDS(UNIT.TO.FIRE(SOLUTION)) GT 0
          SUBTRACT 1 FROM NUC.ROUNDS(UNIT.TO.FIRE(SOLUTION))
          PERFORM DETONATION GIVEN XDGZ(SOLUTION),YDGZ(SOLUTION),
          SIZE(UNIT.TO.FIRE(SOLUTION)),IYIELD(SOLUTION),JROW(SOLUTION),
          KCOL(SOLUTION)
    PRINT 3 LINES THUS
                          ATTRIBUTES OF TANKS
X COORDINATE  Y COORDINATE     TANK.DEAD

    FOR EVERY TANK IN TANK.SET(TARGET), DO
       PRINT 1 LINE WITH X.TANK(TANK), Y.TANK(TANK),TANK.DEAD(TANK) THUS
******.       ******.        **
    LOOP
    PRINT 1 LINE THUS
                          ATTRIBUTES OF TROOPS
    PRINT 2 DOUBLE LINE THUS
X COORDINATE   Y COORDINATE    TRANS.FACTOR   TROOP.DEAD    LETHAL DOSE          ACCUM.DOSE   T.LETHAL   T.IMPAIR.NUC

    FOR EVERY TROOP IN TROOP.SET(TARGET), DO
       PRINT 1 DOUBLE LINE WITH X.TROOP(TROOP), Y.TROOP(TROOP),
       TRANS.FACTOR(TROOP),TROOP.DEAD(TROOP),LETHAL.DOSE(TROOP),
       ACCUM.DOSE(TROOP),T.LETH(TROOP),T.IMPAIR.NUC(TROOP) THUS
******.       ******.         **             **            *****.               *****.       ******.     ******.
    LOOP
       ELSE
    ''      NEED TO LOOP TO NEXT BATTERY
            PRINT 1 LINE THUS
    CANNOT SHOOT THIS BATTERY. OUT OF BULLETS.
       ALWAYS
    LOOP
    STOP
    END ''OF MAIN
```

```
ROUTINE TO READ.RESERVE
READ NCOLS
READ SRC.NROWS, SRC.NYIELDS
READ MRC.NROWS, MRC.NYIELDS
RESERVE SRC.YIELDS(*) AS SRC.NYIELDS
RESERVE MRC.YIELDS(*) AS MRC.NYIELDS
READ SRC.YIELDS
READ MRC.YIELDS
RESERVE SRC.P.COVERAGE(*,*,*,*) AS SRC.NYIELDS BY NTABLES BY SRC.NROWS BY
        NCOLS
RESERVE MRC.P.COVERAGE(*,*,*,*) AS MRC.NYIELDS BY NTABLES BY MRC.NROWS BY
        NCOLS
RESERVE SRC.RANGES(*) AS SRC.NROWS
RESERVE MRC.RANGES(*) AS MRC.NROWS
RESERVE SRC.TABLE.RT(*,*,*) AS SRC.NYIELDS BY NTABLES BY NCOLS
RESERVE MRC.TABLE.RT(*,*,*) AS MRC.NYIELDS BY NTABLES BY NCOLS
READ SRC.TABLE.RT
READ MRC.TABLE.RT
READ SRC.RANGES
READ MRC.RANGES
READ SRC.P.COVERAGE
READ MRC.P.COVERAGE
RESERVE MSD.SRC(*,*) AS SRC.NROWS BY SRC.NYIELDS
RESERVE MSD.MRC(*,*) AS MRC.NROWS BY MRC.NYIELDS
RESERVE CD90.SRC(*) AS SRC.NROWS
RESERVE CEP.SRC(*) AS SRC.NROWS
RESERVE HOB.SRC(*,*,*)  AS SRC.NYIELDS BY SRC.NROWS BY NTABLES
RESERVE PEH.SRC(*)  AS SRC.NROWS
RESERVE SRC.MIN.RD(*,*,*) AS SRC.NYIELDS BY SRC.NROWS BY NTABLES
READ SRC.MIN.RD
RESERVE MRC.MIN.RD(*,*,*) AS MRC.NYIELDS BY MRC.NROWS BY NTABLES
READ MRC.MIN.RD
RESERVE SRC.EXP.RD(*,*,*) AS SRC.NYIELDS BY SRC.NROWS BY NTABLES
READ SRC.EXP.RD
RESERVE MRC.EXP.RD(*,*,*) AS MRC.NYIELDS BY MRC.NROWS BY NTABLES
READ MRC.EXP.RD
READ CD90.SRC
READ CEP.SRC
READ HCE.SRC
READ PEH.SRC
RESERVE CD90.MRC(*) AS MRC;NROWS
RESERVE CEP.MRC(*) AS MRC.NROWS
RESERVE HOE.MRC(*,*,*)  AS MRC.NYIELDS BY MRC.NROWS BY NTABLES
RESERVE PEH.MRC(*)  AS MRC.NROWS
READ CD90.MRC
READ CEP.MRC
READ HCE.MRC
READ PEH.MRC
READ MSD.SRC
READ MSD.MRC
RESERVE CD90.RT(*) AS 25
RESERVE RD.RT(*) AS 21
RESERVE D.CD90(*) AS 21
RESERVE DISPLACED.COVERAGE AS 21 BY 25
READ CD90.RT
READ RD.RT
READ D.CD90
READ DISPLACED.COVERAGE
RESERVE A.OVER(*,*) AS 2 BY 11
READ A.OVER
RESERVE A.DYNAMIC(*,*) AS 2 BY 10
READ A.DYNAMIC
RESERVE GZ.RD(*,*) AS 2 BY 11
READ GZ.RD
RETURN
END ''OF READ.RESERVE
```

```
ROUTINE TO INITIALIZE
      DEFINE M1 AND GI.JOE AS INTEGER VARIABLES
      DEFINE I AND J AS INTEGER VARIABLES
      DEFINE R, THETA AND F AS REAL VARIABLES
      FOR EVERY TARGET, DO
         LET J = 50
         FOR I = 1 TO J,DO
            CREATE A TANK CALLED M1
            LET R = UNIFORM.F(0.,RT(TARGET),1)
            LET THETA = UNIFORM.F(0.,2*PI.C,1)
            LET X.TANK(M1) = XT(TARGET)+R*COS.F(THETA)
            LET Y.TANK(M1) = YT(TARGET)+R*SIN.F(THETA)
            FILE M1 IN TANK.SET(TARGET)
         LOOP
         LET J = 50
         FOR I = 1 TO J,DO
            CREATE A TROOP CALLED GI.JOE
            LET R = UNIFORM.F(0.,RT(TARGET),1)
            LET THETA = UNIFORM.F(0.,2*PI.C,1)
            LET X.TROOP(GI.JOE) = XT(TARGET)+R*COS.F(THETA)
            LET Y.TROOP(GI.JOE) = YT(TARGET)+R*SIN.F(THETA)
            LET LETHAL.DOSE(GI.JOE)=NORMAL.F(0650.,050.,1)
            LET F= UNIFORM.F(0.,1.,1)
            IF .5 LT F LE 1
               LET TRANS.FACTOR(GI.JOE) = .01
            ALWAYS
            IF .1 LT F LE .5
               LET TRANS.FACTOR(GI.JOE) = .3
            ALWAYS
            IF .0 LE F LE .1
               LET TRANS.FACTOR(GI.JOE) = 1.
            ALWAYS
            FILE GI.JOE IN TROOP.SET(TARGET)
         LOOP
      LOOP
END ''OF INITIALIZE
```

```
ROUTINE FOR ANALYSIS GIVEN TYPE, SIZE, RT, RANGE, TARGET,
BATTERY, POLICY
DEFINE TYPE, SIZE, I, J, K, S, TARGET, BATTERY AS INTEGER VARIABLES
DEFINE RT,RANGE,COVERAGE,POLICY AS REAL VARIABLES
IF SIZE = 1 ''THIS IS A SRC BATTERY
   IF RANGE GT SRC.RANGES(SRC.NROWS)
      LET COVERAGE = -1. ''AN ERROR CODE MEANING OUT OF RANGE
      GO TO 10
   ELSE
      FOR J = 1 TO SRC.NROWS, WITH SRC.RANGES(J) GE RANGE,
      FIND THE FIRST CASE
         FOR I = 1 TO SRC.NYIELDS, DO
            FOR K = 1 TO NCOLS, WITH SRC.TABLE.RT(I,TYPE,K)
            GE RT, FIND THE FIRST CASE, IF NONE,
               LET COVERAGE = -2. ''AN ERROR CODE. TARGET TOO BIG
               GO TO 20
            OTHERWISE
            CREATE A SOLUTION CALLED S
            IF K = 1,
               LET COVERAGE = SRC.P.COVERAGE(I,TYPE,J,K)
            ELSE
               LET COVERAGE=EXP.COVERAGE(SIZE,I,TYPE,J,K,RT)
            ALWAYS
            IF COVERAGE GE POLICY,
              CALL OFFSET.COVERAGE GIVEN COVERAGE,I,J,K YIELDING
               XLGZ(S) ,YDGZ(S) AND COVERAGE
            ALWAYS
            IF COVERAGE GE POLICY,
               LET UNIT.TO.FIRE(S)=BATTERY
               LET IYIELD(S)=I
               LET JROW(S)=J
               LET KCOL(S)=K
               LET PCT(S)=COVERAGE
               FILE S IN LISTING(TARGET)
            ALWAYS
'20'   LOOP
'10' RETURN
ELSE ''THIS IS A MRC BATTERY
   IF RANGE GT MRC.RANGES(MRC.NROWS)
      LET COVERAGE = -1. ''AN ERROR CODE MEANING OUT OF RANGE
      GO TO 30
   ELSE
      FOR J = 1 TO MRC.NROWS, WITH MRC.RANGES(J) GE RANGE,
      FIND THE FIRST CASE
         FOR I = 1 TO MRC.NYIELDS, DO
            FOR K = 1 TO NCOLS, WITH MRC.TABLE.RT(I,TYPE,K)
            GE RT, FIND THE FIRST CASE, IF NONE,
               LET COVERAGE = -2. ''AN ERROR CODE. TARGET TOO BIG
               GO TO 40
            OTHERWISE
            CREATE A SOLUTION CALLED S
            IF K = 1,
               LET COVERAGE = MRC.P.COVERAGE(I,TYPE,J,K)
            ELSE
               LET COVERAGE=EXP.COVERAGE(SIZE,I,TYPE,J,K,RT)
            ALWAYS
            IF COVERAGE GE POLICY,
              CALL OFFSET.COVERAGE GIVEN COVERAGE,I,J,K YIELDING
               XDGZ(S) ,YDGZ(S) AND COVERAGE
            ALWAYS
            IF COVERAGE GE POLICY,
               LET UNIT.TO.FIRE(S)=BATTERY
               LET IYIELD(S)=I
               LET JROW(S)=J
               LET KCOL(S)=K
               LET PCT(S)=COVERAGE
               FILE S IN LISTING(TARGET)
            ALWAYS
'40'   LOOP
'30' RETURN
END ''CP ANALYSIS
```

```
ROUTINE FOR EXP.COVERAGE GIVEN SIZE, I, TYPE, J, K, RT
DEFINE SIZE, I, TYPE, J, K AS INTEGER VARIABLES
DEFINE RT, PCT AS REAL VARIABLES
IF SIZE = 1 ''THIS IS A SRC BATTERY
   LET PCT=INTERP(SRC.TABLE.RT(I,TYPE,K-1),RT,SRC.TABLE.RT(I,TYPE,K),
           SRC.P.COVERAGE(I,TYPE,J,K-1),SRC.P.COVERAGE(I,TYPE,J,K))
ELSE ''THIS IS A MRC BATTERY
   LET PCT=INTERP(MRC.TABLE.RT(I,TYPE,K-1),RT,MRC.TABLE.RT(I,TYPE,K),
           MRC.P.COVERAGE(I,TYPE,J,K-1),MRC.P.COVERAGE(I,TYPE,J,K))
ALWAYS
RETURN WITH PCT
END ''OF EXP.COVERAGE


ROUTINE TO OFFSET.COVERAGE GIVEN C.IN,I, J, K
        YIELDING XOUT, YOUT, AND C.OUT
DEFINE D, C.IN, C.OUT, X, XCOUT, Y, Y2, YOUT, DELX, A, B AS REAL VARIABLES
DEFINE I, J, K, L, M, FLAG  AS INTEGER VARIABLES
PERFORM MAX.DISTANCE GIVEN J AND I YIELDING D, XOUT, YOUT AND FLAG
IF FLAG LT 0 ''CANNOT SATISFY TROOP SAFETY FOR ALL UNITS
   LET C.OUT = 0.
   RETURN
ALWAYS
IF D EQ 0
LET C.OUT = C.IN
RETURN
ALWAYS
IF SIZE(BATTERY)=1, ''THIS IS A SRC BATTERY
   LET Y=SRC.MIN.RD(I,J,TYPE(TARGET))/RT(TARGET)
   LET X=CD90.SRC(J)/RT(TARGET)
   LET Y2=D/CD90.SRC(J)
ELSE  ''THIS IS A MRC BATTERY
   LET Y=MRC.MIN.RD(I,J,TYPE(TARGET))/RT(TARGET)
   LET X=CD90.MRC(J)/RT(TARGET)
   LET Y2=D/CD90.MRC(J)
ALWAYS
IF Y GT 10. LET Y = 10. ALWAYS ''SHOULD USE POINT TARGET.
IF Y2 LT .3 ''OFFSET HAS NO EFFECT
   LET XOUT=XT(TARGET)
   LET YOUT=YT(TARGET)
   LET C.OUT=C.IN
   RETURN
OTHERWISE
FOR L=1 TO 21 WITH Y2 LT RD.RT(L), FIND THE FIRST CASE
LET DELX=INTERP(RD.RT(L-1),Y2,RD.RT(L),D.CD90(L-1),D.CD90(L))
LET X=X*DELX ''ADDING D/CD90 EFFECT TO CD90/RT
FOR L=1 TO 21 WITH Y LT RD.RT(L), FIND THE FIRST CASE
IF X LE .1 ''CD90/RT HAS NO EFFECT. COMPUTE AND RETURN.
   LET C.OUT=INTERP(RD.RT(L-1),Y,RD.RT(L),DISPLACED.COVERAGE(L-1,1),
                  DISPLACED.COVERAGE(L,1))
RETURN
ALWAYS
FOR M=1 TO 25 WITH X LT CD90.RT(M), FIND THE FIRST CASE
   LET A=INTERP(CD90.RT(M-1),X,CD90.RT(M),DISPLACED.COVERAGE(L,M-1),
         DISPLACED.COVERAGE(L,M))
   LET B=INTERP(CD90.RT(M-1),X,CD90.RT(M),DISPLACED.COVERAGE(L-1,M-1),
         DISPLACED.COVERAGE(L-1,M))
   LET C.OUT=INTERP(RD.RT(L-1),Y,RD.RT(L),B,A)
RETURN
END ''OF OFFSET.COVERAGE
```

```
ROUTINE TO INTERP GIVEN A,B,C,D,F
DEFINE A,B,C,D,E,F AS REAL VARIABLES
LET E = D+((F-D)*(B-A)/(C-A))
RETURN WITH E
END ''OF INTERP

ROUTINE FOR MAX.DISTANCE GIVEN J, I  YIELDING D, X, Y AND COUNT
DEFINE X, Y, MIN, DIST, D  AS REAL VARIABLES
DEFINE I,J,COUNT,IMIN AS INTEGER VARIABLES
LET X=XT(TARGET)
LET Y=YT(TARGET)
IF SIZE(BATTERY) = 1 ''THIS IS A SRC BATTERY
   LET MSD = MSD.SRC(J,I)
ELSE ''THIS IS A MRC BATTERY
   LET MSD = MSD.MRC(J,I)
ALWAYS
LET COUNT = 1
'10' LET MIN = RINF.C
FOR I=1 TO N.COMPANY, DO
   LET DIST=SQRT.F((XC(I)-X)**2 +  (YC(I)-Y)**2)-CO.RADIUS(I)
   IF DIST LT MIN
     LET MIN = DIST
     LET IMIN=I
   ALWAYS
LOOP
   LET D=SQRT.F((X-XT(TARGET))**2+(Y-YT(TARGET))**2)
IF MIN GE MSD, RETURN OTHERWISE
   LET X=X +  (X-XC(IMIN))*(MSD-MIN)/(MIN+CO.RADIUS(IMIN))
   LET Y=Y +  (Y-YC(IMIN))*(MSD-MIN)/(MIN+CO.RADIUS(IMIN))
ADD 1 TO COUNT
IF COUNT LT 10, GO TO 10 ALWAYS
LET COUNT = -1 ''CANNOT SOLVE IN 10 STEPS
RETURN
END ''OF MAX.DISTANCE
```

```
ROUTINE DETONATION GIVEN X,Y,SIZE,IYIELD,JROW,KCOL
DEFINE X, Y, HOB, PEH, R, SIGMA, THETA, YIELD, CHANCE,
   RD.OVER.PRESSURE, RD.DYNAMIC.PRESSURE, RD.HEAT, REACTION.TIME
   AS REAL VARIABLES
DEFINE SIZE,JROW,KCOL,IYIELD AS INTEGER VARIABLES
IF SIZE = 1
   LET SIGMA = 1.1774*CEP.SRC(JROW)
   LET YIELD = SRC.YIELDS(IYIELD)
   LET PEH = PEH.SRC(JROW)
   LET HOB = HOB.SRC(IYIELD,JROW,TYPE(TARGET))
ELSE
   LET SIGMA = 1.1774*CEP.MRC(JROW)
   LET YIELD = MRC.YIELDS(IYIELD)
   LET PEH = PEH.MRC(JROW)
   LET HOB = HOB.MRC(IYIELD,JROW,TYPE(TARGET))
ALWAYS
LET R = NORMAL.F(0.,SIGMA,1)
LET THETA = UNIFORM.F(0.,PI.C,1)
LET X = X+R*COS.F(THETA)
LET Y = Y+R*SIN.F(THETA)
LET YIELD =NORMAL.F(YIELD,YIELD/10.,1)
LET HOB=NORMAL.F(HOB,PEH/.67,1)
PRINT 1 LINE THUS
------- BURST PARAMETERS FOR DETONATION ARE ------------------------
LIST X,Y,YIELD,HOB
LET RD.OVER.PRESSURE = OVER.PRESSURE(YIELD,25.)
FOR EVERY TANK IN TANK.SET(TARGET) DO
   LET CHANCE = UNIFORM.F(0., 1., 1)
   LET R=SQRT.F((X-X.TANK(TANK))**2 + (Y-Y.TANK(TANK))**2
              + (HOB-ZT(TARGET))**2)
   IF (R/RD.OVER.PRESSURE LE .5) OR
      (.01*(NEUTRON(R,YIELD)+GAMMA(R,YIELD))   GT  18000)
      LET TANK.DEAD(TANK) = 3
   ELSE
      IF PROBABILITY(R/RD.OVER.PRESSURE) GT CHANCE
         LET TANK.DEAD(TANK) = 3
      ALWAYS
   ALWAYS
LOOP
LET RD.HEAT = HEAT(YIELD,20.)
LET RD.OVER.PRESSURE = OVER.PRESSURE(YIELD,10.)
LET RD.DYNAMIC.PRESSURE = DYNAMIC.PRESSURE(YIELD,8.)
FOR EVERY TROOP IN TROOP.SET(TARGET) DO
   LET CHANCE = UNIFORM.F(0., 1., 1)
   LET R=SQRT.F((X-X.TROOP(TROOP))**2 + (Y-Y.TROOP(TROOP))**2)
   LET REACTION.TIME = GAMMA.F(1., 1., 1)
'' SEE IF TROOP IS A THERMAL CASUALTY
   IF ((TRANS.FACTOR(TROOP) = 1) ''TROOP EXPOSED'' AND
      (PROBABILITY(R/RD.HEAT) GT CHANCE) ''MIGHT GET BURNED'' AND
      (REACTION.TIME GT .1)) ''TOO SLOW''
         LET TROOP.DEAD(TROOP) = 3
         GO TO LOOP
   ALWAYS
```

```
'' SEE IF TROOP IS AN OVERPRESSURE CASUALTY
   IF (R/RD.OVER.PRESSURE) LE .5
      LET TROOP.DEAD(TROOP) = 3
   ELSE
      IF PROBABILITY(R/RD.OVER.PRESSURE) GT CHANCE
         LET TROOP.DEAD(TROOP) = 3
         GO TO LOOP
      ALWAYS
   ALWAYS
'' SEE IF TROOP IS A DYNAMIC PRESSURE CASUALTY
   IF (((R/RD.DYNAMIC.PRESSURE) LE .5)
      AND (TRANS.FACTOR(TROOP)=1)
      AND (ARRIVAL.TIME(R,YIELD) LT REACTION.TIME))
      LET TROOP.DEAD(TROOP) = 3
   ELSE
      IF ((PROBABILITY(R/RD.DYNAMIC.PRESSURE) GT CHANCE)
         AND (TRANS.FACTOR(TROOP)=1)
         AND (ARRIVAL.TIME(R,YIELD) LT REACTION.TIME))
         LET TROOP.DEAD(TROOP) = 3
         GO TO LOOP
      ALWAYS
   ALWAYS
'' SEE IF TROOP IS A RADIATION CASUALTY
   ADD TRANS.FACTOR(TROOP)*((NEUTRON(R,YIELD)+GAMMA(R,YIELD))) TO
        ACCUM.DOSE(TROOP)
   IF ACCUM.DOSE(TROOP) GT 18000.
      LET TROOP.DEAD(TROOP) = 3
   ALWAYS
   IF 8000. LT ACCUM.DOSE(TROOP) LT 18000.
      LET TROOP.DEAD(TROOP) = 2
      LET T.LETH(TROOP) =RANDI.F(2*24*60,5*24*60,1)
   ALWAYS
   IF 3000. LT ACCUM.DOSE(TROOP) LT 8000.
      LET TROOP.DEAD(TROOP) = 2
      LET T.IMPAIR.NUC(TROOP) = RANDI.F(30,45,1)
      LET T.LETH(TROOP) =RANDI.F(2*24*60,5*24*60,1)
   ALWAYS
   IF 2000. LT ACCUM.DOSE(TROOP) LT 3000.
      LET TROOP.DEAD(TROOP) = 1
      LET T.LETH(TROOP) =RANDI.F(2*24*60,5*24*60,1)
   ALWAYS
   IF LETHAL.DOSE(TROOP) LT ACCUM.DOSE(TROOP) LT 2000.
      LET TROOP.DEAD(TROOP) = 0
      LET T.IMPAIR.NUC(TROOP) = RANDI.F(30,60,1)
      LET T.LETH(TROOP) =RANDI.F(2*24*60,5*24*60,1)
   ALWAYS
'LOOP' LOOP
RETURN
END ''OF DETONATION
```

```
ROUTINE GAMMA GIVEN R AND YIELD YIELDING G
DEFINE G, R, YIELD AS REAL VARIABLES
LET G = 46166*(EXP.C**((.5599*SQRT.F(YIELD))+(.0001*YIELD*R)))/
      (EXP.C**(.0058*R))
RETURN WITH G
END ''OF GAMMA

ROUTINE NEUTRON GIVEN R AND YIELD YIELDING N
DEFINE N, R, YIELD AS REAL VARIABLES
IF (R-150*LOG.E.F(YIELD)) GT 0
   LET N = (2368.47/(R-150*LOG.E.F(YIELD)))**5.896
ELSE
   LET N = 18000
ALWAYS
RETURN WITH N
END ''OF NEUTRON

ROUTINE HEAT GIVEN YIELD AND H YIELDING RD
DEFINE H, RD, YIELD AS REAL VARIABLES
LET RD=1561*(YIELD**.5051)/(H**.4885)
RETURN WITH RD
END ''OF HEAT

ROUTINE FOR OVER.PRESSURE GIVEN  YIELD, P  YIELDING RD
DEFINE  YIELD, P, RD AS REAL VARIABLES
DEFINE I,J AS INTEGER VARIABLES
FOR J = 1 TO 11, WITH A.OVER(1,J) GE P, FIND THE FIRST CASE
IF NONE, LET RD = 1.0 ''TO AVOID DIVISION BY 0'' RETURN WITH RD
OTHERWISE
LET RD =(INTERP(A.OVER(1,J-1),P,A.OVER(1,J),
        A.OVER(2,J-1),A.OVER(2,J)))*YIELD**.33
RETURN WITH RD
END ''OF OVER.PRESSURE

ROUTINE FOR DYNAMIC.PRESSURE GIVEN YIELD, P YIELDING RD
DEFINE YIELD, P, RD AS REAL VARIABLES
DEFINE I,J AS INTEGER VARIABLES
FOR J = 1 TO 10, WITH A.DYNAMIC(1,J) GE P, FIND THE FIRST CASE
IF NONE, LET RD = 1.0 ''TO AVOID DIVISION BY 0'' RETURN WITH RD
OTHERWISE
LET RD =(INTERP(A.DYNAMIC(1,J-1),P,A.DYNAMIC(1,J),
        A.DYNAMIC(2,J-1),A.DYNAMIC(2,J)))*YIELD**.33
RETURN WITH RD
END ''OF DYNAMIC.PRESSURE

ROUTINE FOR ARRIVAL.TIME GIVEN R, YIELD YIELDING T
DEFINE R, YIELD, T AS REAL VARIABLES
LET T = ((.0028*R)-.45)*(YIELD**.33)
END ''OF ARRIVAL.TIME

ROUTINE FOR PROBABILITY GIVEN Z YIELDING P
DEFINE Z AND P AS REAL VARIABLES
DEFINE I AND J AS INTEGER VARIABLES
FOR J = 1 TO 11 WITH Z LE GZ.RD(1,J), FIND THE FIRST CASE
IF NONE, LET P = 0. RETURN WITH P OTHERWISE
LET P = INTERP(GZ.RD(1,J-1),Z,GZ.RD(1,J),GZ.RD(2,J-1),GZ.RD(2,J))
RETURN WITH P
END ''OF PROBABILITY
```

```
BATTERY  SIZE      X         Y       ROUNDS
   1       1        0.        0.        5
   2       2     1000.0       0.        5
   3       1     1000.0     500.0       5
   4       2      500.0       0.        5
   5       1     1500.0     250.0       5

COMPANY       X           Y         Z          RADIUS
   1       2000.00      500.0       0.         200
   2       2000.00       0.         0.         200
   3       2000.00     -500.0       0.         200

ATTRIBUTES OF TARGET
     TYPE          XT              YT             ZT            RT             N.LISTING        N.TROOP.SET
  1              1    9500.000000       0.             0.          1400.000000             2              50

     N.TANK.SET
  1              50

ATTRIBUTES OF EVERY SOLUTION IN LISTING ( TARGET )
     UNIT.TO.FIRE   XDGZ            YDGZ          IYIELD          JROW           KCOL             PCT
                 2    9900.000000       0.                      2             8               5          .442987
                 4    9900.000000       0.                      2             8               5          .442987

     N.LISTING
                 1
                 1

ATTRIBUTES OF TARGET
     TYPE          XT              YT             ZT            RT             N.LISTING        N.TROOP.SET
  2              4    8000.000000       0.             0.           400.000000             5              50

     N.TANK.SET
  2              50

ATTRIBUTES OF EVERY SOLUTION IN LISTING ( TARGET )
     UNIT.TO.FIRE   XDGZ            YDGZ          IYIELD          JROW           KCOL             PCT
                 2    8000.000000       0.                      1             6               1          .970000
                 4    8000.000000       0.                      1             7               1          .970000
                 1    8000.000000       0.                      2             7               2          .882000
                 3    8000.000000       0.                      2             7               2          .882000
                 5    8000.000000       0.                      2             6               2          .882000

     N.LISTING
                 1
                 1
                 1
                 1
                 1

ATTRIBUTES OF TARGET
     TYPE          XT              YT             ZT            RT             N.LISTING        N.TROOP.SET
  3              5    6000.000000       0.             0.           300.000000             5              50

     N.TANK.SET
  3              50

ATTRIBUTES OF EVERY SOLUTION IN LISTING ( TARGET )
     UNIT.TO.FIRE   XDGZ            YDGZ          IYIELD          JROW           KCOL             PCT
                 2    6100.000000       0.                      1             4               3          .562333
                 4    6200.000000       0.                      1             5               3          .385161
                 5    6000.000000       0.                      2             4               6          .375000
                 1    6000.000000       0.                      2             5               6          .360000
                 3    6000.000000       0.                      2             5               6          .360000

     N.LISTING
                 1
                 1
                 1
                 1
                 1
```

ATTRIBUTES OF SOLUTION

UNIT.TO.FIRE	XDGZ	YDGZ	IYIELD	JROW	KCOL	PCT
2	9900.000000	0.	2	8	5	.442987

N.LISTING 0

-------- BURST PARAMETERS FOR DETONATION ARE ------------------------

X	Y	YIELD	HOB
9894.968750	17.707565	7.269897	131.652115

ATTRIBUTES OF TANKS

X COORDINATE	Y COORDINATE	TANK.DEAD
10064.	1165.	0
9836.	-50.	3
9706.	-277.	3
9960.	-798.	0
9555.	561.	0
9505.	626.	0
9939.	-1067.	0
10413.	-807.	0
8891.	1.	0
9435.	-794.	0
10001.	407.	0
9252.	396.	0
8663.	-1030.	0
9465.	-12.	0
9903.	-732.	0
9011.	-119.	0
9623.	1054.	0
8875.	557.	0
10556.	-785.	0
8494.	80.	0
9036.	400.	0
9762.	-283.	3
9570.	218.	0
10075.	-925.	0
8686.	1097.	0
9661.	-48.	3
9627.	-183.	3
9597.	300.	3
10043.	770.	0
9533.	-191.	0
9231.	-703.	0
8582.	-183.	0
9586.	515.	0
10676.	-143.	0
10164.	-440.	0
9431.	30.	3
9543.	-100.	3
9850.	-888.	0
9411.	-79.	0
9507.	-248.	0
9499.	-4.	0
9297.	-1382.	0
10180.	-407.	0
8377.	515.	0
9238.	-55.	0
9350.	338.	0
8773.	862.	0
9243.	121.	0
9453.	761.	0
8791.	32.	0

ATTRIBUTES OF TROOPS

X COORDINATE	Y COORDINATE	TRANS.FACTOR	TROOP.DEAD	LETHAL DOSE	ACCUM.DOSE	T.LETHAL	T.IMPAIR.NUC
10453.	646.	0	3	631.	0.	0.	0.
8967.	1138.	0	0	608.	2.	0.	0.
8931.	410.	1	0	616.	1992.	6271.	34.
8830.	-1167.	0	0	585.	1.	0.	0.
9349.	628.	0	3	635.	0.	0.	0.
10013.	130.	0	0	642.	1095.	5430.	32.
10037.	-884.	0	3	682.	0.	0.	0.
9170.	-824.	0	0	639.	387.	0.	0.
8912.	365.	0	0	611.	20.	0.	0.
9775.	289.	0	3	663.	644.	0.	0.
9246.	-230.	1	3	571.	0.	0.	0.
9591.	-75.	0	3	702.	617.	0.	0.
9529.	-412.	0	3	702.	0.	0.	0.
9132.	227.	0	3	598.	0.	0.	0.
8789.	-1012.	0	0	713.	1.	0.	0.
9874.	-307.	1	3	663.	0.	0.	0.
8902.	-164.	0	0	649.	732.	4336.	49.
9575.	-180.	0	3	720.	511.	0.	0.
9654.	-418.	0	3	605.	0.	0.	0.
9667.	121.	0	0	649.	767.	3656.	50.
9903.	-11.	0	0	594.	1975.	5322.	42.
10071.	1273.	0	0	611.	5.	0.	0.
8695.	-556.	0	0	674.	114.	0.	0.
9497.	0.	0	3	620.	477.	0.	0.
9122.	-318.	0	0	599.	87.	0.	0.
9527.	74.	0	2	612.	15490.	7128.	0.
9170.	-571.	0	0	562.	42.	0.	0.
8117.	171.	0	0	750.	.	0.	0.
9565.	330.	0	3	710.	0.	0.	0.
8253.	-296.	1	0	672.	68.	0.	0.
9496.	-128.	0	3	512.	443.	0.	0.
10557.	-647.	0	0	579.	40.	0.	0.
8944.	237.	0	0	675.	31.	0.	0.
9360.	498.	0	2	592.	7631.	6271.	30.
9455.	-24.	0	3	607.	0.	0.	0.
8462.	915.	0	0	635.	19.	0.	0.
8523.	319.	0	0	604.	3.	0.	0.
9582.	225.	0	2	611.	15324.	4527.	0.
9830.	871.	0	1	594.	2316.	3229.	0.
9733.	-385.	0	3	663.	0.	0.	0.
9762.	-400.	0	3	552.	0.	0.	0.
10061.	540.	0	3	717.	0.	0.	0.
9426.	-600.	1	3	684.	0.	0.	0.
8563.	-557.	1	0	543.	222.	0.	0.
9594.	-79.	0	0	618.	621.	5137.	40.
8368.	404.	0	0	709.	25.	0.	0.
10077.	-266.	0	2	531.	17344.	5494.	0.
9321.	-617.	0	0	786.	77.	0.	0.
8809.	903.	0	0	592.	79.	0.	0.
9514.	-41.	0	3	571.	495.	0.	0.

ATTRIBUTES OF SOLUTION

UNIT.TO.FIRE	XDGZ	YDGZ	IYIELD	JROW	KCOL	PCT
2	8000.000000	0.	1	6	1	.970000

N.LISTING
0

-------- BURST PARAMETERS FOR DETONATION ARE ------------------------

X	Y	YIELD	HOB
7956.378906	-13.019145	1.994571	135.251236

ATTRIBUTES OF TANKS

X COORDINATE	Y COORDINATE	TANK.DEAD
8220.	-267.	0
7710.	-85.	3
7864.	-257.	3
8082.	-11.	3
7942.	31.	3
8230.	303.	0
8115.	125.	3
8190.	-65.	3
7965.	67.	3
8006.	37.	3
7935.	169.	3
8067.	94.	3
8393.	6.	0
7792.	-308.	0
8080.	-267.	0
7956.	261.	0
7927.	3.	3
8095.	311.	0
7898.	25.	3
7966.	-163.	3
7952.	-97.	3
8072.	-110.	3
7977.	-178.	3
7957.	-86.	3
7729.	-84.	0
7957.	69.	3
8101.	35.	3
8344.	87.	0
7732.	250.	0
7798.	-128.	3
7866.	58.	3
7971.	18.	3
7803.	-22.	0
7792.	145.	3
8173.	130.	3
8003.	-148.	3
8205.	200.	0
7926.	173.	3
7853.	-159.	3
7755.	185.	0
8014.	-17.	3
7838.	-154.	3
7830.	102.	3
8110.	-153.	3
8069.	216.	0
8186.	180.	3
8097.	-57.	3
7749.	56.	3
8088.	-5.	3
7880.	-343.	0

ATTRIBUTES OF TROOPS

X COORDINATE	Y COORDINATE	TRANS.FACTOR	TROOP.DEAD	LETHAL DOSE	ACCUM.DOSE	T.LETHAL	T.IMPAIR.NUC
8111.	-96.	1	3	717.	57992.	0.	0.
8047.	68.	1	3	596.	0.	0.	0.
7997.	-5.	0	0	685.	986.	4760.	54.
8071.	388.	0	3	553.	0.	0.	0.
8115.	43.	0	3	678.	596.	0.	0.
7745.	279.	0	3	623.	0.	0.	0.
8025.	-28.	1	3	684.	86880.	0.	0.
8207.	16.	0	3	700.	448.	0.	0.
8124.	285.	0	3	615.	0.	0.	0.
8126.	36.	0	3	602.	578.	0.	0.
8223.	80.	0	3	643.	0.	0.	0.
8206.	-118.	0	3	561.	423.	0.	0.
8132.	-228.	0	2	646.	12461.	4187.	0.
7746.	-142.	0	3	652.	456.	0.	0.
8021.	-14.	0	0	674.	888.	7163.	55.
7918.	142.	0	3	609.	18488.	0.	0.
7937.	137.	0	3	674.	19097.	0.	0.
7588.	-22.	0	0	573.	1029.	6224.	34.
8033.	20.	0	3	614.	24556.	0.	0.
7733.	-273.	0	3	691.	0.	0.	0.
7943.	239.	0	2	667.	13412.	6776.	0.
7834.	-58.	0	0	604.	691.	4906.	34.
8267.	174.	0	3	605.	0.	0.	0.
8114.	2.	0	3	763.	620.	0.	0.
8230.	107.	0	3	733.	0.	0.	0.
7734.	-166.	0	3	639.	425.	0.	0.
8200.	-102.	0	2	560.	13160.	5331.	0.
7736.	-8.	0	2	618.	14876.	6152.	0.
8084.	-161.	0	2	676.	16231.	4417.	0.
7767.	-146.	0	3	651.	479.	0.	0.
8077.	-11.	0	3	605.	21537.	0.	0.
8004.	-39.	0	0	690.	931.	3366.	38.
7979.	-73.	0	0	624.	889.	2902.	45.
8325.	-71.	0	3	703.	0.	0.	0.
8356.	86.	0	3	668.	0.	0.	0.
8052.	-171.	0	2	660.	16858.	2954.	0.
7976.	377.	0	3	626.	0.	0.	0.
7865.	53.	0	0	668.	742.	3534.	56.
7979.	-21.	0	0	641.	1071.	3480.	33.
7884.	-81.	0	0	661.	765.	4357.	55.
7663.	-23.	0	3	694.	0.	0.	0.
8068.	38.	0	3	655.	21335.	0.	0.
7892.	161.	0	3	599.	561.	0.	0.
8087.	212.	0	2	729.	13093.	5783.	0.
7901.	103.	0	0	654.	696.	5677.	37.
7640.	-136.	0	3	638.	0.	0.	0.
7933.	87.	0	0	620.	753.	6877.	51.
7307.	29.	0	0	639.	887.	6580.	57.
8281.	-145.	0	3	583.	0.	0.	0.
7802.	-223.	0	2	712.	13086.	6277.	0.

ATTRIBUTES OF SOLUTION

UNIT.TO.FIRE 2 XDGZ 6100.000000 YDGZ 0. IYIELD 1 JROW 4 KCOL 3 PCT .562333

M.LISTING 0

-------- BURST PARAMETERS FOR DETONATION ARE ------------------------

X	Y	YIELD	HOB
6081.753506	-2.394111	1.951000	68.847504

ATTRIBUTES OF TANKS

X COORDINATE	Y COORDINATE	TANK.DEAD
6112.	229.	3
6116.	-150.	3
5965.	-26.	3
6100.	-196.	3
5942.	120.	3
5785.	-85.	3
5738.	128.	0
6016.	-5.	3
6002.	4.	3
6003.	.	3
6238.	-81.	3
5873.	-48.	3
5902.	21.	3
6201.	-17.	3
6213.	-191.	3
5945.	28.	3
5955.	-9.	3
6071.	125.	3
5942.	165.	3
6007.	-3.	3
5835.	124.	0
5940.	17.	3
5878.	-143.	3
5785.	-164.	0
5947.	-13.	3
5981.	-24.	3
5722.	-62.	0
6195.	47.	3
5768.	43.	0
6100.	-34.	3
6072.	167.	3
5866.	191.	3
6092.	-12.	3
5835.	42.	3
6149.	156.	3
6275.	-116.	0
6112.	-265.	0
5843.	244.	0
5936.	139.	3
6176.	2.	3
5979.	43.	3
5856.	102.	3
5769.	-149.	0
6047.	-75.	3
6028.	-54.	3
6006.	42.	3
5906.	-93.	3
6117.	1.	3
6027.	-11.	3
6041.	203.	3

ATTRIBUTES OF TROOPS

X COORDINATE	Y COORDINATE	TRANS.FACTOR	TROOP.DEAD	LETHAL DOSE	ACCUM.DOSE	T.LETHAL	T.IMPAIR.NUC
5967.	-183.	1	3	615.	0.	0.	0.
5971.	46.	0	3	620.	21382.	0.	0.
5981.	-13.	0	3	646.	23137.	0.	0.
5920.	61.	0	3	717.	581.	0.	0.
6135.	-237.	0	3	695.	462.	0.	0.
6086.	48.	0	3	618.	28247.	0.	0.
6211.	-48.	0	3	637.	20049.	0.	0.
5962.	-204.	0	3	637.	471.	0.	0.
6249.	81.	0	3	606.	554.	0.	0.
6084.	-182.	0	2	674.	17043.	3688.	0.
5972.	-55.	1	3	641.	0.	0.	0.
6031.	142.	0	3	534.	18864.	0.	0.
6192.	39.	0	0	617.	722.	5076.	31.
5953.	90.	0	3	657.	18452.	0.	0.
5849.	-33.	0	3	602.	470.	0.	0.
6057.	95.	0	0	580.	756.	6735.	33.
5852.	85.	0	2	622.	13635.	5189.	0.
5778.	-89.	0	3	653.	0.	0.	0.
5844.	-75.	0	2	610.	13521.	3405.	0.
5968.	-27.	0	0	672.	726.	5607.	34.
6199.	150.	0	2	579.	16307.	6008.	0.
5874.	187.	0	3	554.	0.	0.	0.
6219.	-163.	0	2	664.	15278.	6499.	0.
6087.	43.	0	3	599.	28880.	0.	0.
5823.	-137.	0	3	695.	0.	0.	0.
5954.	11.	0	0	633.	691.	4000.	37.
6199.	89.	0	0	634.	639.	5602.	56.
5801.	-128.	0	3	645.	0.	0.	0.
5900.	77.	0	3	543.	0.	0.	0.
6196.	225.	0	2	630.	13259.	3197.	0.
6115.	-246.	0	2	738.	13645.	4930.	0.
6167.	173.	0	2	710.	16124.	6689.	0.
6002.	104.	0	3	573.	20348.	0.	0.
5857.	89.	0	3	696.	460.	0.	0.
5957.	-156.	0	3	687.	533.	0.	0.
6135.	233.	0	3	656.	462.	0.	0.
6170.	32.	1	3	709.	0.	0.	0.
5859.	-107.	0	2	614.	13608.	5505.	0.
6022.	261.	0	3	623.	422.	0.	0.
6122.	-156.	0	3	740.	614.	0.	0.
5914.	-31.	0	3	650.	589.	0.	0.
6007.	-15.	0	0	654.	840.	6181.	49.
5888.	-188.	0	3	704.	424.	0.	0.
5884.	59.	0	2	586.	15487.	3607.	0.
6165.	-220.	0	2	548.	14194.	5173.	0.
6061.	220.	0	3	499.	489.	0.	0.
6111.	96.	0	0	612.	768.	5948.	30.
5871.	220.	0	3	593.	0.	0.	0.
5898.	235.	0	3	677.	0.	0.	0.
6016.	-11.	0	0	682.	875.	3517.	34.

APPENDIX C

GLOSSARY

A. WEAPONS EFFECTS

Alpha particle: A radioactive emmision identical with the helium nucleus, having a mass of four and an electric charge of two positive units.

Attenuation: A decrease in intensity due to absorption or scattering, but not due to geometric reduction as a result of range.

Beta particle: A radioactive emmision identicle in composition to an electron with the possible exception that beta particles possess a very high speed.

Induced Radioactivity: Radioactivity produced in certain elements by the capture of free neutrons. In the area immediately below Ground Zero the elements of sodium, manganese, aluminum and silicon are are easily induced.

Neutron: A particle of mass one and without any electric charge. Neutrons are present in all elements except light hydrogen and are required to initiate the detonation process in nuclear weapons.

Rad: One of many measures of radiation density or destructive power. It represents the absorption of 100 ergs of ionizing radiation per gram of absorbing material, such as body tissue.

B. TARGET ANALYSIS

Functionally impaired: Personnel who exhibit some decreased ability to perform their assigned task, but are not incapacitated. Charicterized by vomiting, diarrhea, nausea, lethargy, depression and mental disorientation.

Immediate permanent incapacitation (IP) Immediate permanent incapacitation is the ;most severe of the radiation criteria and causes death in the shortest amount of time. Personnel performing tasks which are physically demanding become incapacitated within 5 minutes of exposure. They remain in this state for 1 to 2 days at whick time death occurs.

Immediate transient incapacitation (IT) Personnel receining this dose become incapacitated within 5 minutes of expcsure and remain sc for 30 to 45 minutes. Personnel then reccver, but are functionally impaired until death which occurs in 4 to 6 days.

Latent lethality (LL) Personnel exposed to this their lethal dose become functicnally impaired within 2 hcurs of exposure. More than half of this group will die within several weeks.

Incapacitated: An individual who performs at 50 % or less of his pre-irradiation performance level.

Radiaticn exposure status: A unit wide rating relating the average accumulated dose to the risk warranted exposure of pending missions.

Minimum separaticn distance (MSD): The distance friendly troops must be from the burst to insure less than 2% chance of damage.

Light damage: Light damage does not prevent the immediate use of an item. Scme repair by the user will usually be needed to make the item operational.

Moderate damage: Mcderate damage prevents use of an item until extensive repairs are made. This degree of damage is normally sufficient tc deny use cf the equipment. In most situaticns, achievement of this degree of damage will be sufficient to support tactical operations.

Severe damage: Severe damage prevents use of an item permanently. There may be some situaticns such as the attack cn a bridge where severe damage is the only adequate degree of destruction.

LIST OF REFERENCES

1. Glasstone, Samuel The Effect of Nuclear Weapons, United States Department of Defense, 1977

2. FM 101-31-3 Staff Officers Field Manual, Nuclear Weapons Employment Effects Data. Department of the Army, Washington D.C., June 1977

3. ST 3-97 Nuclear Weapons Employment Concepts. U.S. Army Chemical School, Ft. McClellan, Ala. Undated.

4. FM 101-31-1, Nuclear Weapons Employment Doctrine and Procedures. Department of the Army, Washington D.C. March 1977

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Technical Information Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0142 Naval Postgraduate School Monterey, California 93940	2
3.	Department Chairman, Code 55 Department of Operations Research Naval Postgraduate School Monterey, California 93940	1
4.	Chief TRADOC Research Element Monterey Naval Postgraduate School Monterey, California 93940	1
5.	Professor James K. Hartman Code 55Hh Department of Operations Research Naval Postgraduate School Monterey, California 93940	5
6.	Professor Sam H. Parry Code 55PY Department of Operations Research Naval Postgraduate School Monterey, California 93940	2
7.	Headquarters US Army Training and Doctrine Command ATTN: Director, Studies and Analysis Directorate, Mr. S. Goldberg Ft. Monroe, Virginia 23651	1
8.	Mr. Walter Hollis Deputy Under Secretary of the Army (Operations Research) Department of the Army, The Pentagon Washington, D. C. 20310	1
9.	Director Combined Arms Combat Development Activity ATTN: ATZL-CAC-A (Mr. Lee Pleger) Ft. Leavenworth, Kansas 66027	1
10.	Director Combat Analysis Office ATTN: Mr. Kent Pickett US Army Combined Arms Center Ft. Leavenworth, Kansas 66027	1
11.	Command and General Staff College ATTN: Education Advisor Room 123, Bell Hall Ft. Leavenworth, Kansas 66027	1

12. Dr. Wilbur Payne, Director 1
US Army TRADOC Systems Analysis Activity
White Sands Missile Range, New Mexico 88002

13. Commander 1
US Army Concepts and Analysis Agency
ATTN: MCCA-WG
8120 Woodmont Avenue
Bethesda, Maryland 20014

14. Director 1
USATRASANA
ATTN: Mr. Ray Heath
White Sands Missile Range, New Mexico 88002

15. Director 1
USATRASANA
ATTN: ATOR-TCB (Mr. Luis Dominguez)
White Sands Missile Range, New Mexico 88002

16. Director 1
Combat Developments, Studies Division
US Army Armor Agency
Ft. Knox, Kentucky 40121

17. Director 1
Combat Developments
US Army Field Artillery School
Ft. Sill, Oklahoma 73503

18. Director 1
Combat Developments
US Army Infantry School
Ft. Benning, Georgia 31905

19. Captain Joseph C. Fernandez, USA 1
3646 Promontory St.
San Diego California 92109

20. Commandant 1
US Army Chemical School
ATTN: ATZN-CM-TD
Fort McClellan, Alabama 36205

21. Commandant 1
US Army Chemical School
ATTN: ATZN-CM-AS
Fort McClellan, Alabama 36205

22. Commandant 2
US Army Chemical School
ATTN: ATZN-CM-CC
Fort McClellan, Alabama 36205

23. Lawrence Livermore National Laboratory 1
ATTN: Don Blumenthal, Station L-7
Box 808
Livermore, California 94550

Thes
F262
c.1

202086

Thesis
F2623 Fernandez
c.1 A simulation model of
tactical nuclear target
analysis and damage
assessment.

25 AUG 84

27948

202086

Thesis
F2623 Fernandez
c.1 A simulation model of
tactical nuclear target
analysis and damage
assessment.

thesF2623
A simulation model of tactical nuclear t
3 2768 001 01499 6
DUDLEY KNOX LIBRARY